程序代写代做 CS编程辅导

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Topic Overview

程序代写代做 CS编程辅导

- Quick recap of the matrix [illegible] algorithm
- Fox algorithm for parallel [illegible]ication
- Cannon algorithm for para[illegible]ultiplication

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Learning outcome(s) related to this topic

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- Design and develop parallel algorithms for various parallel computing architectures (LO3)

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These slides and enclosed sample code files were prepared by Shageenderan Sapai, PhD postgraduate student, Monash University.

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Quick recap of the matrix multiplication algorithm

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Matrix multiplication

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Assume we have 2 n x n matrices, A we want to find C such that C = A x B

1	4	8
2	5	6
1	5	6

A

X

7	3	4
2	9	6
7	1	9

B

=

71	47	100
66	57	92
59	54	88

C

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$$c_{ij} = \left(a_i \cdot b_j^T\right) = \sum_{k=0}^{n-1} a_{ik} \cdot b_{kj}, \quad 0 \le i < m, \ 0 \le j < l$$

Matrix Multiplication

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1	4	8
2	5	6
1	5	6

A

X

7	3	4
2	9	6
7	1	9

B

=

71		

C

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Matrix Multiplication

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2	5	6
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A

X

7	3	4
2	9	6
7	1	9

B

=

71	47	

C

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Matrix Multiplication

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1	4	8
2	5	6
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A

X

7	3	4
2	9	6
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B

=

71	47	100

C

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Matrix Multiplication

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1	4	8
2	5	6
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A

X

7	3	4
2	9	6
7	1	9

B

=

71	47	100
66		

C

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Matrix Multiplication

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1	4	8
2	5	6
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A

X

7	3	4
2	9	6
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B

=

71	47	100
66	57	92
59	54	88

C

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Serial Algorithm

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A and B nxn matrices AxB

```
void Serial_mat_mult(mt_A,mt int n)
{
  int i,j,k;
for (i=0;i<n;i++){
    for (j=0;j<n;j++){
       C[i][j]=0.0;
       for (k=0;k<n;k++)
           C[i][j]= C[i][j]+A[i][k]*B[k][j];
   }
}
```

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Time Complexity O(n^3) – very slow

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Parallel matrix multiplication algorithm - Fox

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Parallel Matrix Multiplication Algorithm - General

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A and B nxn matrices = xB

- First, Matrix A & B are partitioned so that each process works on a specific submatrix of A & B.
- Each process does a serial matrix multiplication on their local submatrices of A & B and the results are stored in an accumulating sum
- Local submatrices are then communicated around to calculate the final result
- There are different algorithms for how submatrices are communicated, mainly, **Fox algorithm** and **Cannon algorithm**

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Parallel Algorithm – Data Partitioning

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- Parallel matrix multiplication requires [illegible]oning – common methods are Block-Row Partitioning or Block-Column Partitioning.
- Another method is grid or checkerboa[illegible]ing – which is used in Fox and Cannon algorithm
- Say we have *p* number of processes and a square Matrix, M, of size nxn and let q = sqrt(*p*)
- M is partitioned into *p* square blocks (sub matrices) $M_{i,j}$ where 0 <= i, j < q of size n/qxn/q

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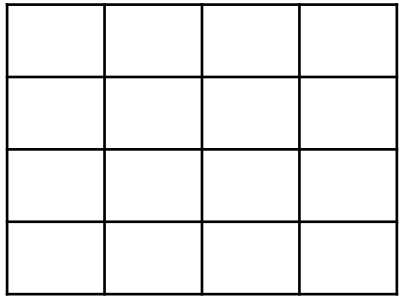
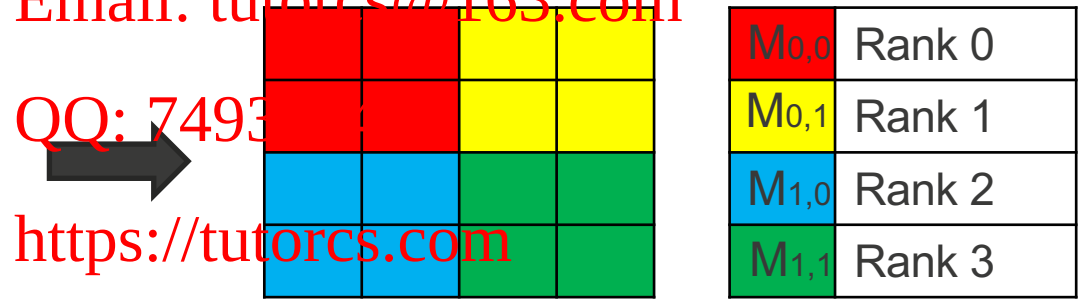
Say p = 4 and n = 4



M

Each submatrix = n/q = 4/sqrt(4) = 2



Fox Algorithm

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- Matrix A & B are **grid partitioned** [illegible]trices $A_{i,j}$ and $B_{i,j}$
- In each step, a one-to-all broadcas[illegible]ws of matrix A and a single-step circular upwards shift of columns in matrix B is done

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- Loop q times
  1. Broadcast diagonal block $A_{i,i}$ to all processors in the same row group
  2. Multiply block of received $A_{i,i}$ with local block $B_{i,j}$ and add to $C_{i,j}$
  3. Send (shift) entire local block $B_{i,j}$ with the same column group
  4. Select block $A_{i,(j+1) \bmod q}$ (where $A_{i,j}$ is the block broadcast in the previous step) and broadcast to all processors in the same row group.
  5. Go to 2.
- Gather all

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Data Partitioning – Fox Algorithm

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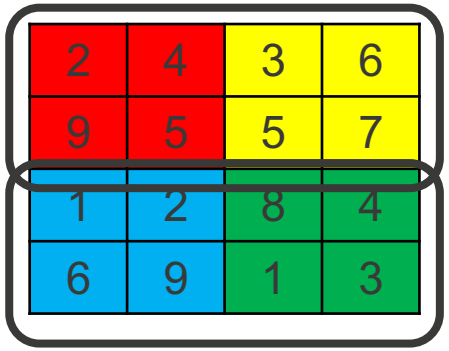
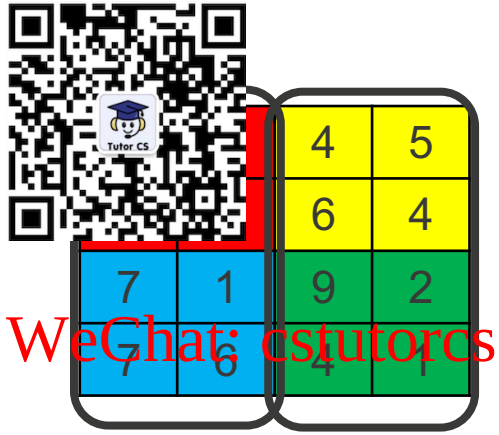
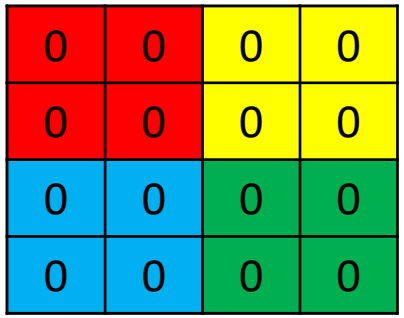


A



B



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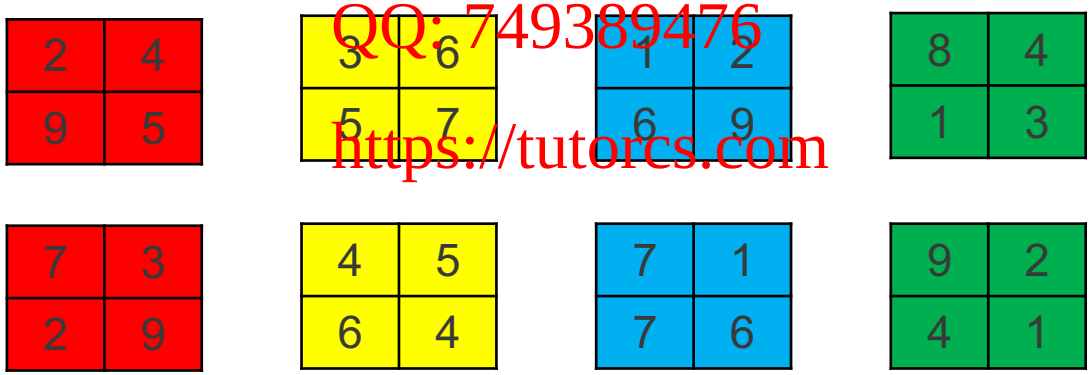
0 1 2 3



Groups	Processors	
Row Group	[0,1]	[2, 3]
Column Group	[0,2]	[1,3]

Loop q times

- Broadcast diagonal block $A_{i,i}$ to all processors in the same row group

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$A_{0,0}$

2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

		4	5
		6	4
		9	2
7	6	4	1

B

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

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0

$A_{0,0}$

2	4
9	5

$A_{i,i}$

0	0
0	0

$B_{0,0}$

7	3
2	9

1

$A_{0,1}$

3	6
5	7

$A_{i,i}$

0	0
0	0

$B_{0,1}$

4	5
6	4

2

$A_{1,0}$

1	2
6	9

$A_{i,i}$

0	0
0	0

$B_{1,0}$

7	1
7	6

3

$A_{1,1}$

8	4
1	3

$A_{i,i}$

0	0
0	0

$B_{1,1}$

9	2
4	1

Loop q times

- Broadcast diagonal block $A_{i,i}$ to all processors in the same row group

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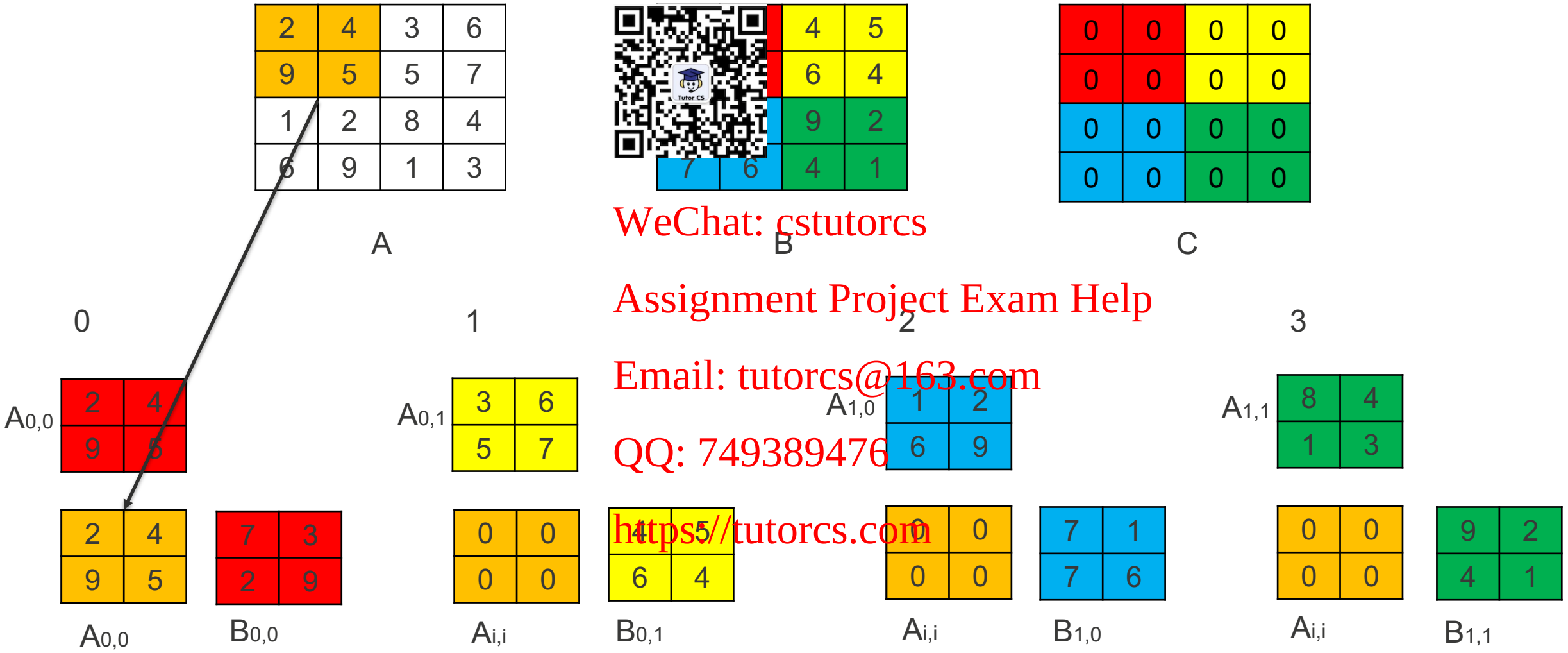

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Loop q times

- Broadcast diagonal block $A_{i,i}$ to all processors in the same row group

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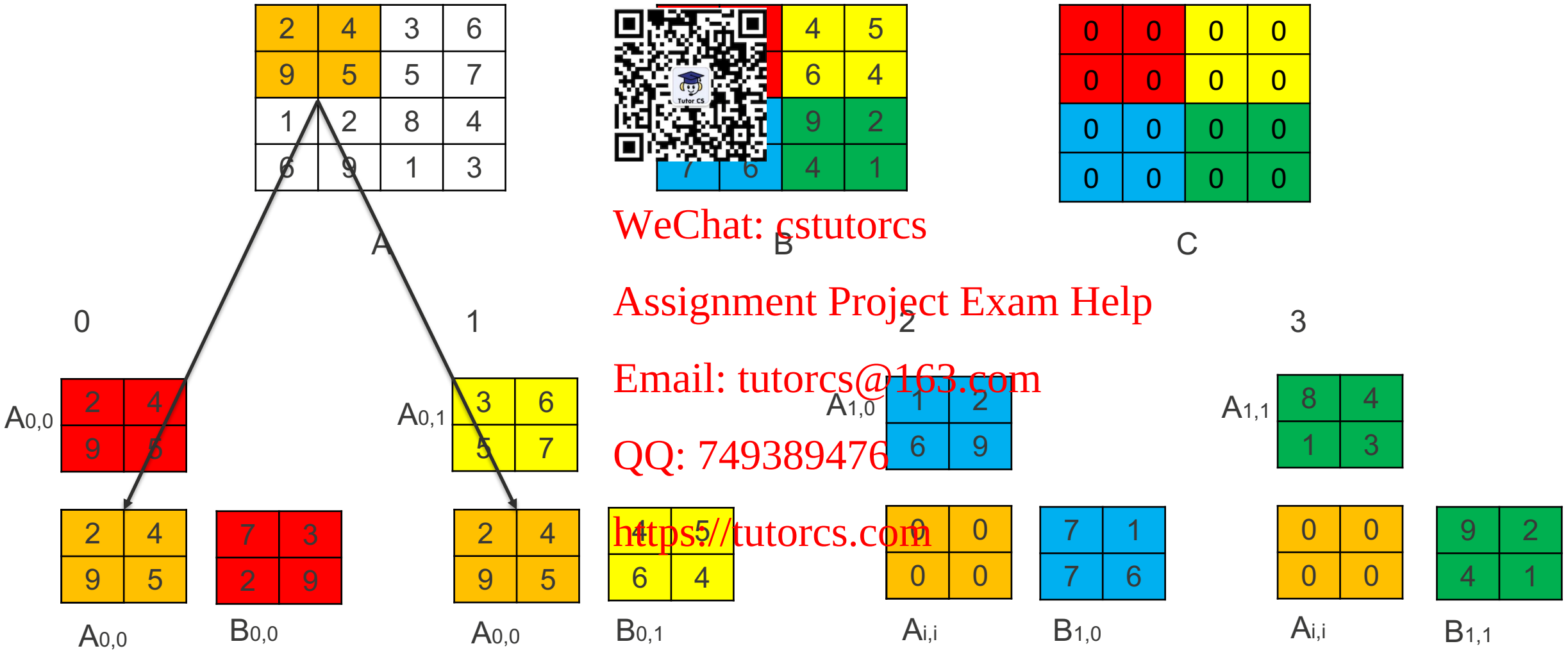

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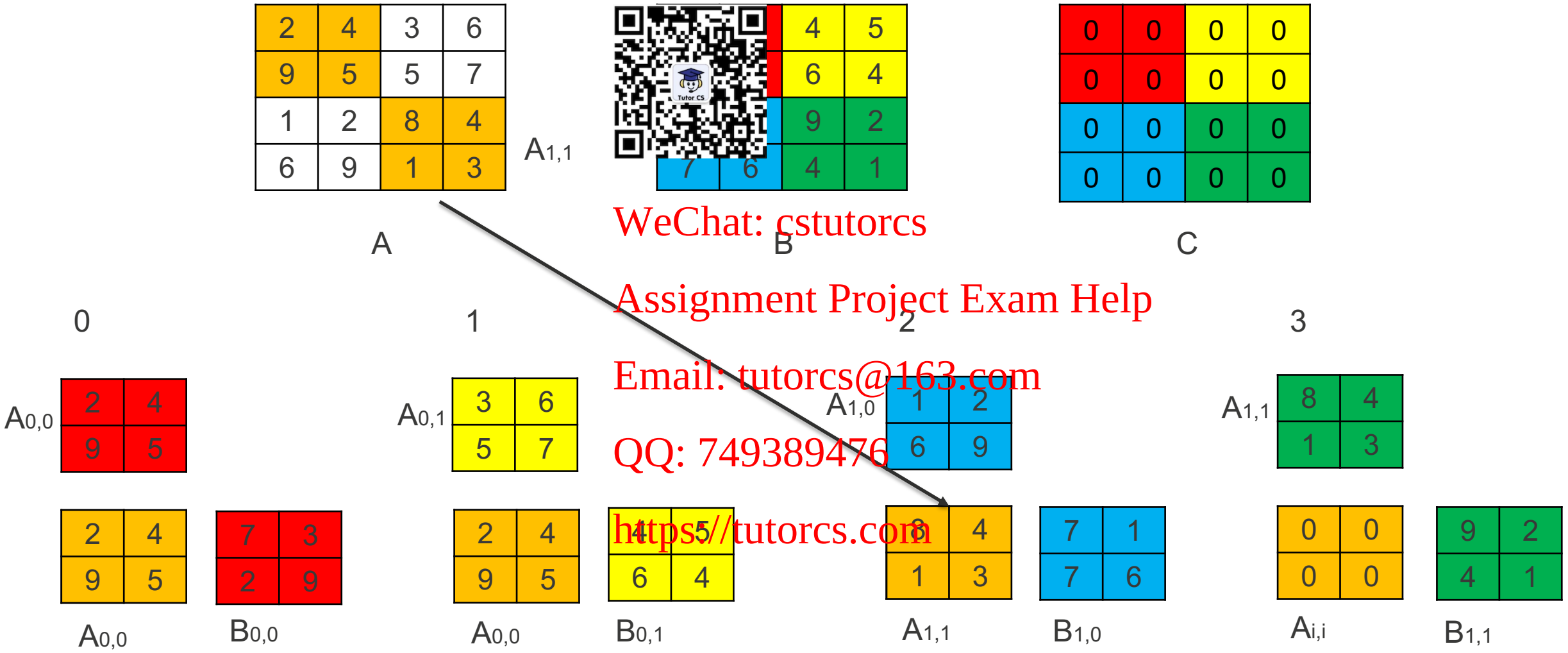
Loop q times

- Broadcast diagonal block $A_{i,i}$ to all processors in the same row group

程序代写代做CS编程辅导



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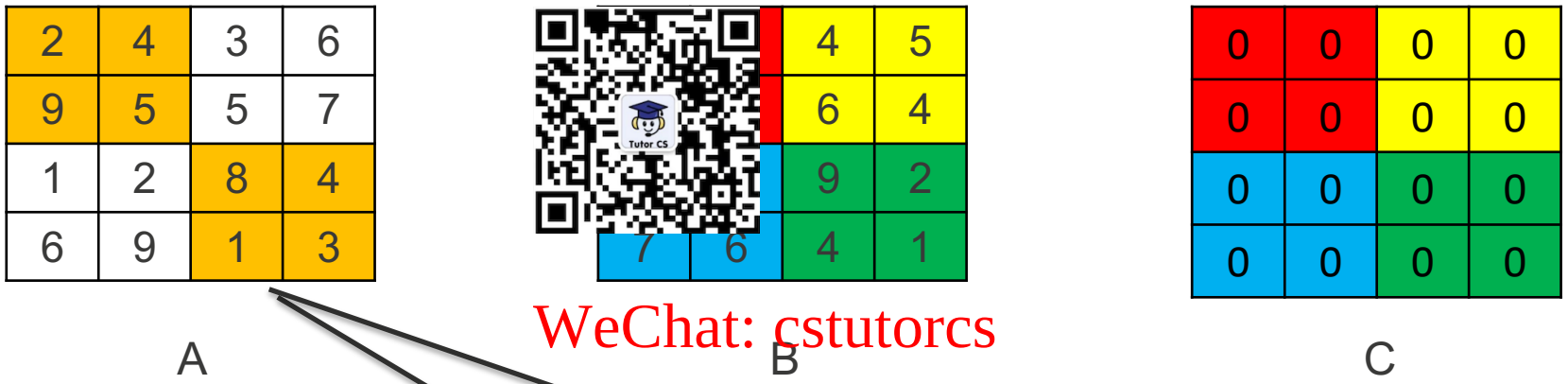
Loop q times

- Broadcast diagonal block $A_{i,i}$ to all processors in the same row group

程序代写代做CS编程辅导



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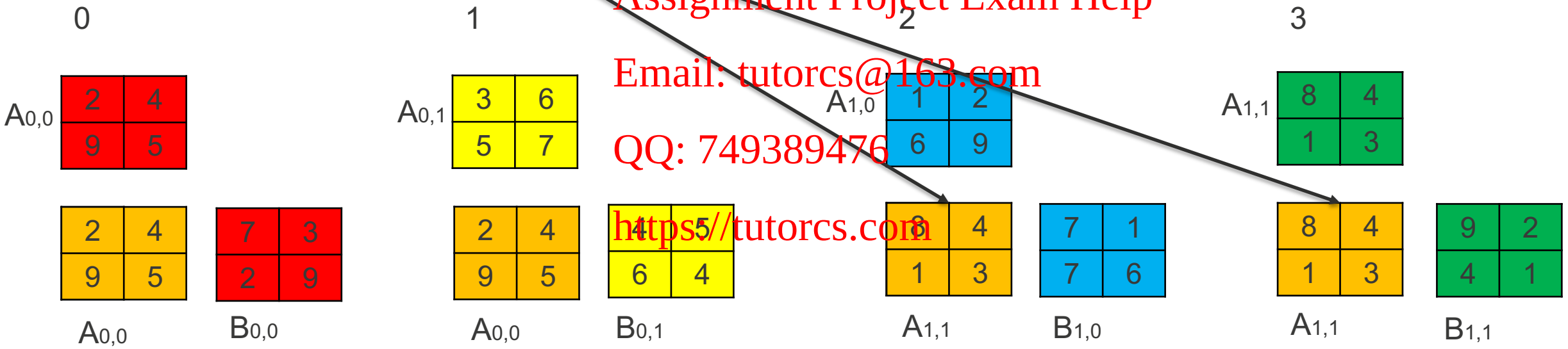

Loop q times

- Multiply block of received A with resident block B and add to C

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2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

		4	5
		6	4
		9	2
7	6	4	1

B

22	42	32	26
73	72	66	65
84	32	88	20
28	19	21	5

C

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0

$A_{0,0}$

2	4
9	5

2	4	x	7	3
9	5		2	9

$A_{0,0}$ $B_{0,0}$

1

$A_{0,1}$

3	6
5	7

2	4	x	4	5
9	5		6	4

$A_{0,0}$ $B_{0,1}$

2

$A_{1,0}$

1	2
6	9

8	4	x	7	1
1	3		7	6

$A_{1,1}$ $B_{1,0}$

3

$A_{1,1}$

8	4
1	3

8	4	x	9	2
1	3		4	1

$A_{1,1}$ $B_{1,1}$

Loop q times

- Multiply block of received A with resident block B and add to C

程序代写代做 CS编程辅导

2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

7	3	4	5
2	9	6	4
7	6	9	2
		4	1

B

22	42	32	26
73	72	66	65
84	32	88	20
28	19	21	5

C

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0

$A_{0,0}$

2	4
9	5

2	4	7	3
9	5	2	9

x

$A_{0,0}$ $B_{0,0}$

1

$A_{0,1}$

3	6
5	7

2	4	4	5
9	5	6	4

x

$A_{0,0}$ $B_{0,1}$

2

$A_{1,0}$

1	2
6	9

8	4	7	1
1	3	7	6

x

$A_{1,1}$ $B_{1,0}$

3

$A_{1,1}$

8	4
1	3

8	4	9	2
1	3	4	1

x

$A_{1,1}$ $B_{1,1}$

Loop q times

1. Send (shift) entire local block B up within the same column group

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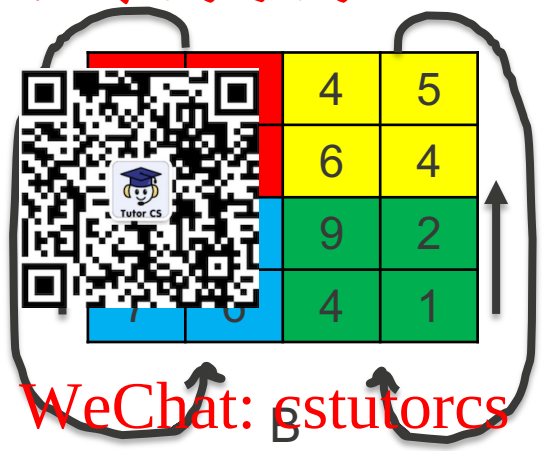

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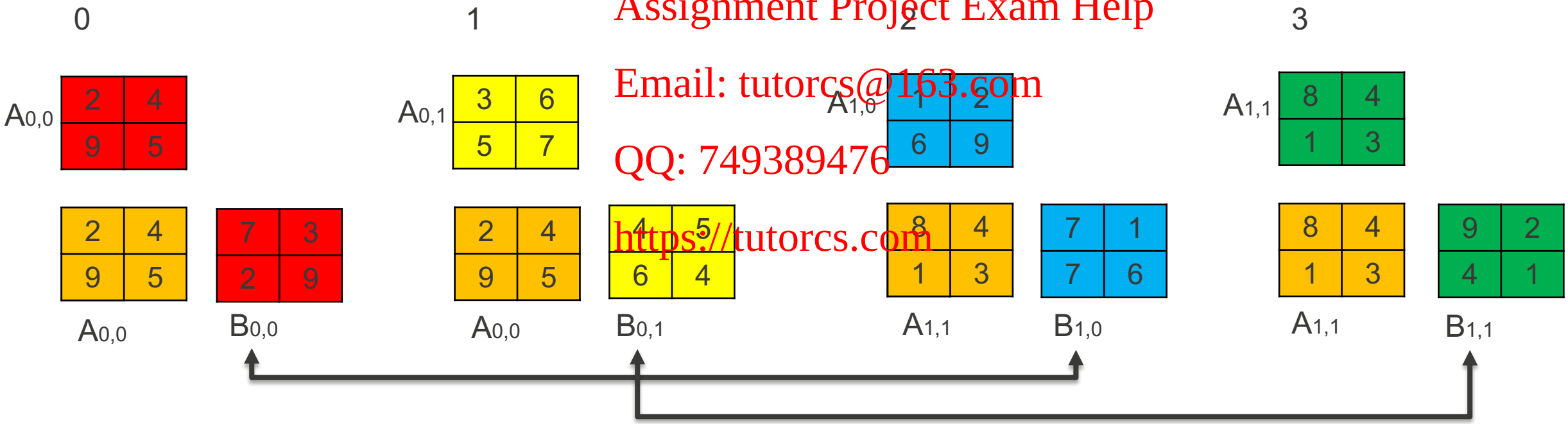

Loop q times

- Send (shift) **entire** resident block B up one step

程序代写代做 CS编程辅导

2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

		9	2
		4	1
		4	5
		6	4

B

22	42	32	26
73	72	66	65
84	32	88	20
28	19	21	5

C

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0

$A_{0,0}$

2	4
9	5

2	4
9	5

$A_{0,0}$

7	1
7	6

$B_{0,0}$

1

$A_{0,1}$

3	6
5	7

2	4
9	5

$A_{0,0}$

9	2
4	1

$B_{0,1}$

2

$A_{1,0}$

1	2
6	9

8	4
1	3

$A_{1,1}$

7	3
2	9

$B_{1,0}$

3

$A_{1,1}$

8	4
1	3

8	4
1	3

$A_{1,1}$

4	5
6	4

$B_{1,1}$

Loop q times

- Broadcast $A_{i,(j+1) \bmod q}$ to all processors in the same row group

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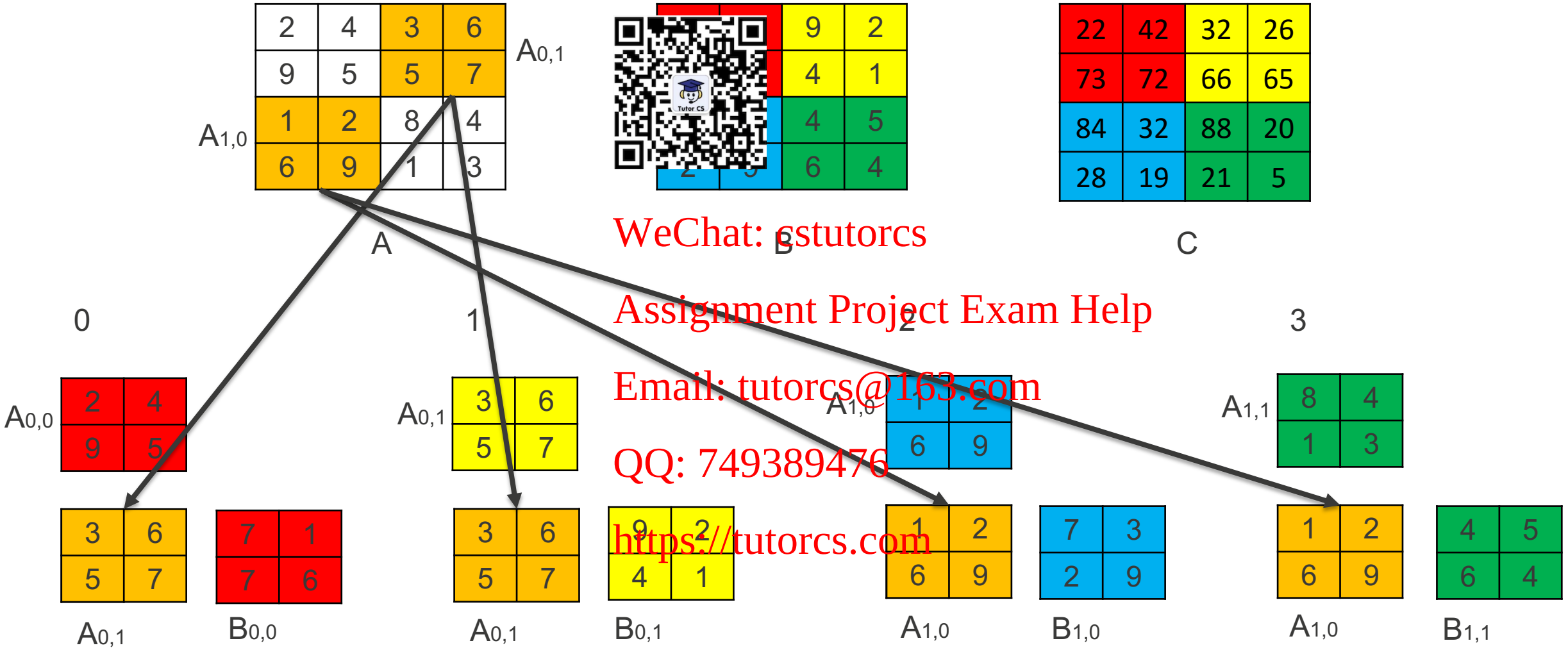

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Loop q times

- Multiply block of received A with resident block B and add to C

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2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

		9	2
		4	1
		4	5
2	9	6	4

B

85	81	83	38
157	119	139	82
95	53	104	33
88	118	99	71

C

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0

$A_{0,0}$

2	4
9	5

3	6	x	7	1	
5	7		7	6	

$A_{0,1}$ $B_{0,0}$

1

$A_{0,1}$

3	6
5	7

3	6	x	9	2	
5	7		4	1	

$A_{0,1}$ $B_{0,1}$

2

$A_{1,0}$

1	2
6	9

1	2	x	7	3	
6	9		2	9	

$A_{1,0}$ $B_{1,0}$

3

$A_{1,1}$

8	4
1	3

1	2	x	4	5	
6	9		6	4	

$A_{1,0}$ $B_{1,1}$

Loop q times

- Multiply block of received A with resident block B and add to C

程序代写代做 CS编程辅导

2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

7	1	9	2
7	6	4	1
7	3	4	5
2	9	6	4

B

85	81	83	38
157	119	139	82
95	53	104	33
88	118	99	71

C

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0

$A_{0,0}$

2	4
9	5

3	6	7	1
5	7	7	6

x

$A_{0,1}$ $B_{0,0}$

1

$A_{0,1}$

3	6
5	7

3	6	9	2
5	7	4	1

x

$A_{0,1}$ $B_{0,1}$

2

$A_{1,0}$

1	2
6	9

1	2	7	3
6	9	2	9

x

$A_{1,0}$ $B_{1,0}$

3

$A_{1,1}$

8	4
1	3

1	2	4	5
6	9	6	4

x

$A_{1,0}$ $B_{1,1}$

- Already looped q(2) times, so now we must:
- Gather All

程序代写代做 CS编程辅导

85	81	8	
157	119	139	82
95	53	104	33
88	118	99	71

C

85	81	83	38
157	119	139	82
95	53	104	33
88	118	99	71

C

Gathered results on Process 0

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Fox Algorithm

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- Tends to be faster than simple par multiplication for large values of n
- Implemented in MPI by creating rc mn communicators which enable easy communication of A & B blocks
- Although dealing with 2D matrices, in coding implementation these are represented using 1D arrays
- Difficult to adapt for non-square matrices i.e. A (mxn) x B (nxm)
- Has high communication overhead because at each step we are sending (relatively) large blocks of local A & B.

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Parallel matrix multiplication algorithm - Cannon

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Cannon Algorithm

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- Matrix A & B are **grid partitioned** trices $A_{i,j}$ and $B_{i,j}$
- Data is moved incrementally in q- ng broadcast algorithm)
- Each process skews matrix $A_{i,j}$ and $B_{i,j}$ to align elements by shifting $A_{i,j}$ by i rows to the left and shifting $B_{i,j}$ by j columns up.
- Multiply local block A with local block B and add to local C
- Loop q-1 times
  1. Shift elements (each A_i row by 1 unit and each B_j column by 1 unit)
  2. Multiply local block A with local block B and add to local C
- Gather all

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Data Partitioning – Cannon Algorithm

程序代写代做 CS编程辅导

2	4	3	6
9	5	5	7
1	2	8	4
6	9	1	3

A

		4	5
		6	4
7	1	9	2
7	6	4	1

B

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

C

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0

2	4
9	5

7	3
2	9

1

3	6
5	7

4	5
6	4

2

1	2
6	9

7	1
7	6

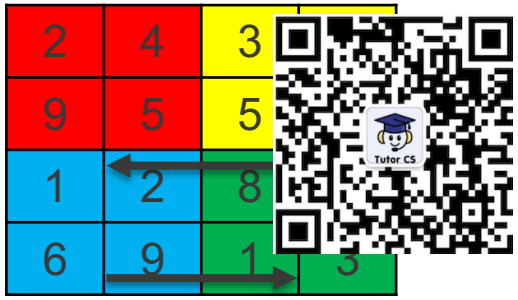
3

8	4
1	3

9	2
4	1

Skew matrix A and B to align elements by shifting $A_{i,j}$ by i rows to the left and shift $B_{i,j}$ by j columns up.

程序代写代做 CS编程辅导



A

B

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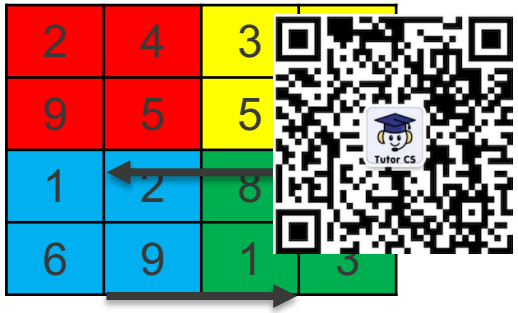
	0	1	2	3
Local A	2 4 9 5	3 6 5 7	1 2 6 9	8 4 1 3
Local B	7 3 2 9	4 5 6 4	7 1 7 6	9 2 4 1

Skew matrix A and B to align elements by shifting A_i by i rows to the left and shift B_i by i columns up.

程序代写代做 CS编程辅导



A

B

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	0	1	2	3
Local A	2 4 9 5	3 6 5 7	8 4 1 3	1 2 6 9
Local B	7 3 2 9	9 8 4 1	7 1 7 6	4 5 6 4

Skew matrix A and B to align elements by shifting A_i by i rows to the left and shift B_i by i columns up.

程序代写代做 CS编程辅导

2	4	3	
9	5	5	
8	4	1	
1	3	6	9

A

7	3	9	2
2	9	4	1
7	1	4	5
7	6	6	4

B

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	0	1	2	3
Local A	2 4 9 5	3 6 5 7	8 4 1 3	1 2 6 9
Local B	7 3 2 9	9 2 4 1	7 1 7 6	4 5 6 4

Loop q-1 times

1. Multiply elements and add to accumulating sum

程序代写代做 CS编程辅导

2	4	3	6
9	5	5	7
8	4	1	2
1	3	6	9

A

3	9	2	
9	4	1	
1	4	5	
7	6	6	4

B

22	42	51	12
73	72	73	17
84	32	16	13
28	19	78	66

C

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0

2	4
9	5

x

7	3
2	9

Local A Local B

1

3	6
5	7

x

9	2
4	1

Local A Local B

2

8	4
1	3

x

7	1
7	6

Local A Local B

3

1	2
6	9

x

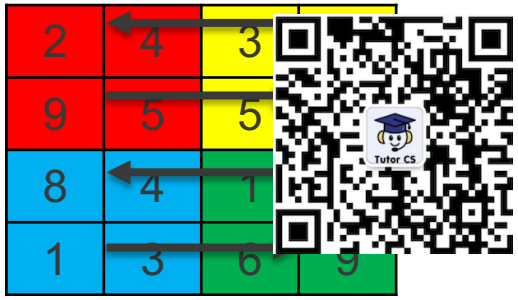
4	5
6	4

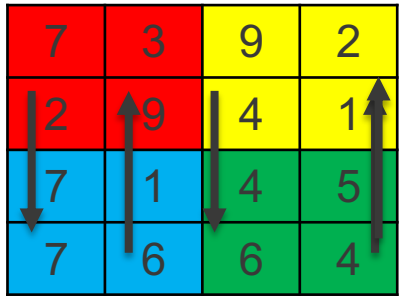
Local A Local B

Loop q1 times

1. Shift elements (each A_i row by 1 unit and each B_i column by 1 unit)

程序代写代做 CS编程辅导





A B

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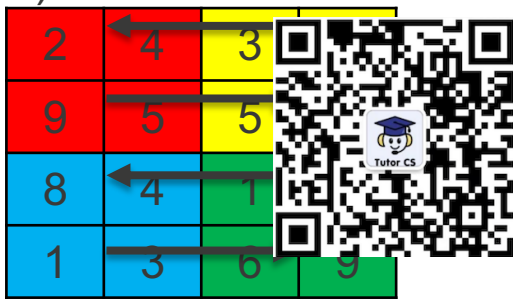
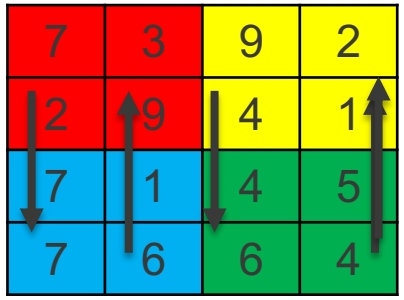
	0	1	2	3
Local A	2 4 9 5	3 6 5 7	8 4 1 3	1 2 6 9
Local B	7 3 2 9	9 2 4 1	7 1 7 6	4 5 6 4

Loop q-1 times

1. Shift elements (each A_i row by 1 unit and each B_i column by 1 unit)

程序代写代做 CS编程辅导





A B

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	0	1	2	3
Local A	3 6 5 7	2 4 9 5	1 2 6 9	8 4 1 3
Local B	7 1 7 6	4 5 6 4	7 3 2 9	9 2 4 1

Loop q-1 times

1. Shift elements (each A_i row by 1 unit and each B_i column by 1 unit)

程序代写代做 CS编程辅导

3	6	2	4
5	7	9	5
1	2	8	4
6	9	1	3

A

7	1	4	5
7	6	6	4
7	3	9	2
2	9	4	1

B

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	0	1	2	3
Local A	3 6 5 7	2 4 9 5	1 2 6 9	8 4 1 3
Local B	7 1 7 6	4 5 6 4	7 3 2 9	9 2 4 1

Loop q-1 times

1. Multiply local block A with local block B and add to local C

程序代写代做 CS编程辅导

3	6	2	4
5	7	9	5
1	2	8	4
6	9	1	3

A

1	4	5	
6	6	4	
3	9	2	
2	9	4	1

B

22	42	51	12
73	72	73	17
84	32	16	13
28	19	78	66

C

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0

3	6
5	7

Local A

x

7	1
7	6

Local B

1

2	4
9	5

Local A

x

4	5
6	4

Local B

2

1	2
6	9

Local A

x

7	3
2	9

Local B

3

8	4
1	3

Local A

x

9	2
4	1

Local B

Loop q-1 times

1. Multiply local block A with local block B and add to local C

程序代写代做 CS编程辅导

3	6	2	4
5	7	9	5
1	2	8	4
6	9	1	3

A

1	4	5	
6	6	4	
3	9	2	
2	9	4	1

B

85	81	83	38
157	119	139	82
95	53	104	33
88	118	99	71

C

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0

3	6
5	7

Local A

x

7	1
7	6

Local B

1

2	4
9	5

Local A

x

4	5
6	4

Local B

2

1	2
6	9

Local A

x

7	3
2	9

Local B

3

8	4
1	3

Local A

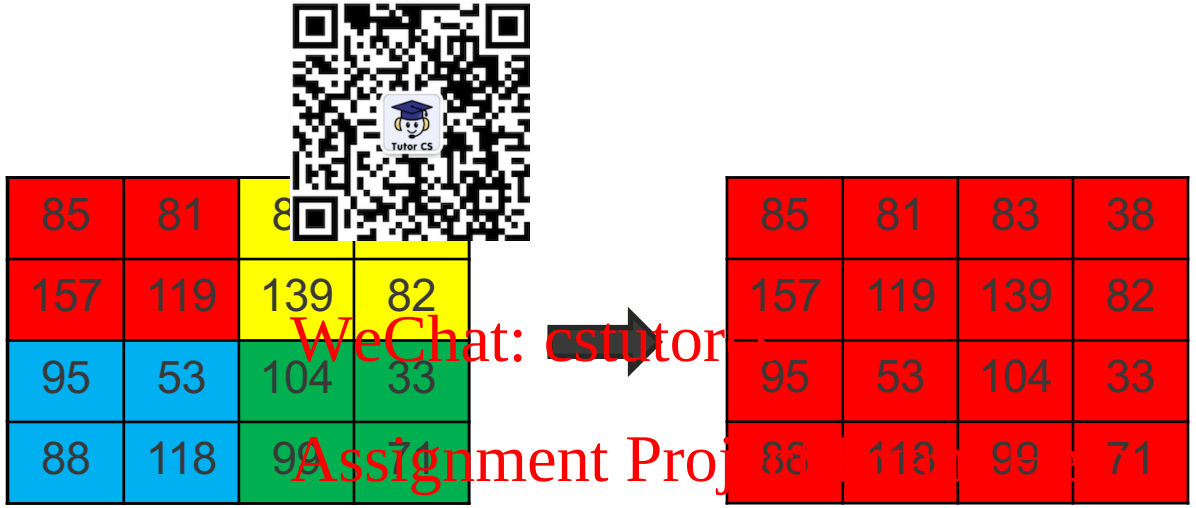
x

9	2
4	1

Local B

- Already looped q-1(1) times, so now we must:
- Gather All

程序代写代做 CS编程辅导



C

C

Gathered results on Process 0

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Cannon Algorithm

程序代写代做 CS编程辅导

- Tends to be faster than simple par[illegible] multiplication for large values of n
- Implemented in MPI by creating ro[illegible]mn communicators which enable easy shifting of data
- Although dealing with 2D matrices, [illegible] implementation these are represented using 1D arrays
- Difficult to adapt for non-square matrices i.e. A (mxn) x B (nxm)
- Has lower communication overhead than Fox algorithm because at each step we are sending less data than in Fox

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Cannon Algorithm – Bigger Example

程序代写代做 CS编程辅导

2	4	3	6	4	4
9	5	5	7	3	3
1	2	8	4	2	2
6	9	1	3	1	1
1	2	8	4	2	2
6	9	1	3	1	1

A

5	4	4			
4	5	5			
7	1	9	2	6	6
7	6	4	1	7	7
7	1	9	2	6	6
7	6	4	1	7	7

B

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

C

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Skew

程序代写代做 CS编程辅导

2	4	3	6	4	4
9	5	5	7	3	3
8	4	2	2	1	2
1	3	1	1	6	9
2	2	1	2	8	4
1	1	6	9	1	3

A

			2	6	6
			1	7	7
7	1	9	2	4	4
7	6	4	1	5	5
7	1	4	5	6	6
7	6	6	4	7	7

B

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

C

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Multiply

程序代写代做 CS编程辅导

2	4	3	6	4	4
9	5	5	7	3	3
8	4	2	2	1	2
1	3	1	1	6	9
2	2	1	2	8	4
1	1	6	9	1	3

A

2	6	6			
1	7	7			
7	1	3	2	4	4
7	6	4	1	5	5
7	1	4	5	6	6
3	6	6	4	1	7

B

22	42	51	12	52	52
73	72	73	17	39	39
84	32	26	6	14	14
28	19	13	3	69	69
28	14	16	13	76	76
14	7	78	66	27	27

C

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Skew

程序代写代做 CS编程辅导

3	6	4	4	2	4
5	7	3	3	9	5
2	2	1	2	8	4
1	1	6	9	1	3
1	2	8	4	2	2
6	9	1	3	1	1

A

2	4	4			
1	5	5			
7	1	4	5	6	6
7	6	6	4	7	7
7	3	9	2	6	6
8	3	4	1	7	7

B

22	42	51	12	52	52
73	72	73	17	39	39
84	32	26	6	14	14
28	19	13	3	69	69
28	14	16	13	76	76
14	7	78	66	27	27

C

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Multiply

程序代写代做 CS编程辅导

3	6	4	4	2	4
5	7	3	3	9	5
2	2	1	2	8	4
1	1	6	9	1	3
1	2	8	4	2	2
6	9	1	3	1	1

A

2	4	4			
1	5	5			
5	6	6			
7	6	6	4	7	7
7	3	9	2	6	6
3	9	4	1	7	7

B

85	81	103	24	80	80
157	119	112	26	100	100
112	46	42	19	90	90
42	26	91	69	96	96
39	35	104	33	102	102
74	106	99	71	40	40

C

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Skew

程序代写代做 CS编程

4	4	2	4	3	6
3	3	9	5	5	7
1	2	8	4	2	2
6	9	1	3	1	1
8	4	2	2	1	2
1	3	1	1	6	9

A

5	6	6			
4	7	7			
2	6	6			
2	9	4	1	7	7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	6	4	1	5	5

B

85	81	103	24	80	80
157	119	112	26	100	100
112	46	42	19	90	90
42	26	91	69	96	96
39	35	104	33	102	102
[illegible]	[illegible]	99	71	40	40

C

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Multiply

程序代写代做 CS编

4	4	2	4	3	6
3	3	9	5	5	7
1	2	8	4	2	2
6	9	1	3	1	1
8	4	2	2	1	2
1	3	1	1	6	9

A

5	6	6			
4	7	7			
2	6	6			
2	9	4	1	7	7
7	1	9	2	4	4
7	6	4	1	5	5

B

141	109	135	50	140	140
199	140	178	91	179	179
123	67	130	39	116	116
102	125	112	74	109	109
123	67	130	39	116	116
102	125	112	74	109	109

C

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- Already looped q-1(2) times, so now we must:
- Gather All

程序代写代做 CS编程辅导

141	109	135	50		
199	140	178	91		
123	67	130	39	116	116
102	125	112	74	109	109
123	67	130	39	116	116
102	125	112	74	109	109

C

141	109	135	50	140	140
199	140	178	91	179	179
123	67	130	39	116	116
102	125	112	74	109	109
123	67	130	39	116	116
102	125	112	74	109	109

C

Gathered results on Process 0

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