



# ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

ΣΧΟΛΗ ΗΜ&ΜΥ

Συστήματα Παράλληλης Επεξεργασίας 1<sup>η</sup> Άσκηση  
Ακ. έτος 2012-2013

Ομάδα 8<sup>η</sup>

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12 Νοεμβρίου 2012

# Πηγαίος κώδικας

## Κοινή βιβλιοθήκη

```
1  /* .....
2  * File Name : common.h
3  * Creation Date : 06-11-2012
4  * Last Modified : Mon 12 Nov 2012 10:06:15 AM EET
5  * Created By : Greg Liras <gregliras@gmail.com>
6  * Created By : Alex Maurogiannis <nalfemp@gmail.com>
7  .....*/
8
9  #ifndef DEBUG_FUNC
10 #define DEBUG_FUNC
11
12 #if main_DEBUG
13 #define debug(fmt,arg...)    fprintf(stdout, "%s: " fmt, __func__ , ##arg)
14 #else
15 #define debug(fmt,arg...)    do { } while(0)
16 #endif /* main_DEBUG */
17
18 #endif /* DEBUG_FUNC */
19
20 #ifndef COMMON_H
21 #define COMMON_H
22
23 #include <stdlib.h>
24 #include <stdio.h>
25 #include <mpi.h>
26
27 double *allocate_2d(int N, int M);
28 double *allocate_2d_with_padding(int N, int M, int max_rank);
29 double *parse_matrix_2d(FILE *fp, int N, int M, double *A);
30 void fprint_matrix_2d(FILE *fp, int N, int M, double *A);
31 void print_matrix_2d(int N, int M, double *A);
32 double timer(void);
33 void usage(int argc, char **argv);
34
35 #ifdef USE_MPI /* USE_MPI */
36 void propagate_with_send(void *buffer, int count , MPI_Datatype datatype, \
37     int root, MPI_Comm comm);
38 void propagate_with_flooding(void *buffer, int count , MPI_Datatype datatype, \
39     int root, MPI_Comm comm);
40 #endif /* USE_MPI */
41
42 #endif /* COMMON_H */
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29     double *p;
30     p = A;
31     for (i = 0; i < N; i++) {
32         for (j = 0; j < M; j++) {
33             if(!fscanf(fp, "%lf", p++)) {
34                 return NULL;
35             }
36         }
37     }
38     return A;
39 }
40
41 void fprintf_matrix_2d(FILE *fp, int N, int M, double *A)
42 {
43     int i,j;
44     double *p;
45     p = A;
46     for (j = 0; j < M; j++) {
47         fprintf(fp, "=");
48     }
49     fprintf(fp, "\n");
50     for (i = 0; i < N; i++) {
51         for (j = 0; j < M; j++) {
52             fprintf(fp, "%lf\t", *p++);
53         }
54         fprintf(fp, "\n");
55     }
56     for (j = 0; j < M; j++) {
57         fprintf(fp, "=");
58     }
59     fprintf(fp, "\n");
60 }
61
62 void print_matrix_2d(int N, int M, double *A)
63 {
64     fprintf_matrix_2d(stdout, N, M, A);
65 }
66
67 double timer(void)
68 {
69     static double seconds = 0;
70     static int operation = 0;
71     struct timeval tv;
72     gettimeofday(&tv, NULL);
73     if (operation == 0) {
74         seconds = tv.tv_sec + (((double) tv.tv_usec)/1e6);
75         operation = 1;
76         return 0;
77     }
78     else {
79         operation = 0;
80         return tv.tv_sec + (((double) tv.tv_usec)/1e6) - seconds;
81     }
82 }
83
84 void usage(int argc, char **argv)
85 {
86     if(argc != 3) {
87         printf("Usage: %s <matrix file> <output file>\n", argv[0]);
88         exit(EXIT_FAILURE);
89     }
90 }
91
92 #ifdef USE_MPI /* USE_MPI */
93 void propagate_with_send(void *buffer, int count, MPI_Datatype datatype, \
94     int root, MPI_Comm comm)
95 {
96     int rank;
97     int i;
98     int max_rank;
99
100     MPI_Comm_rank(comm, &rank);
101     MPI_Comm_size(comm, &max_rank);
102     if(rank == root) {
103         for(i = 0; i < max_rank; i++) {

```

```

104         if(i == rank) {
105             continue;
106         }
107         else {
108             debug("%d\n", i);
109             MPI_Send(buffer, count, datatype, i, root, comm);
110         }
111     }
112 }
113 else {
114     MPI_Status status;
115     MPI_Recv(buffer, count, datatype, root, root, comm, &status);
116 }
117 }
118
119 void propagate_with_flooding(void *buffer, int count , MPI_Datatype datatype, \
120                             int root, MPI_Comm comm)
121 {
122     int rank;
123     int max_rank;
124     int cur;
125
126     MPI_Comm_rank(comm, &rank);
127     MPI_Comm_size(comm, &max_rank);
128
129     if(root != 0) {
130         if(rank == root) {
131             MPI_Send(buffer, count, datatype, 0, root, comm);
132         }
133         if(rank == 0) {
134             MPI_Status status;
135             MPI_Recv(buffer, count, datatype, root, root, comm, &status);
136         }
137     }
138
139     if(rank != 0) {
140         MPI_Status status;
141         MPI_Recv(buffer, count, datatype, (rank-1)/2, root, comm, &status);
142     }
143     cur = 2*rank+1;
144     if(cur < max_rank) {
145         MPI_Send(buffer, count, datatype, cur, root, comm);
146     }
147     if(++cur < max_rank) {
148         MPI_Send(buffer, count, datatype, cur, root, comm);
149     }
150 }
151 #endif /* USE_MPI */

```

## Ζητούμενο 1 Σειριακό Πρόγραμμα

```

1  /* .....
2  * File Name : main.c
3  * Creation Date : 30-10-2012
4  * Last Modified : Thu 08 Nov 2012 09:50:55 AM EET
5  * Created By : Greg Liras <gregliras@gmail.com>
6  * Created By : Alex Maurogiannis <nalfemp@gmail.com>
7  .....*/
8
9  #include <stdio.h>
10 #include <stdlib.h>
11
12 #include "common.h"
13
14 int main(int argc, char **argv)
15 {
16     int i,j,k;
17     int N;
18     double *A;
19     double l;
20     double sec;
21
22     FILE *fp = NULL;
23     usage(argc, argv);
24     /*

```

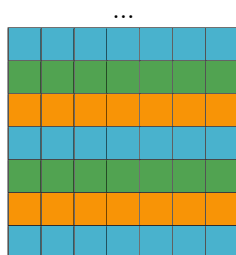
```

25     * Allocate me!
26     */
27     fp = fopen(argv[1], "r");
28     if(fp) {
29         if(!fscanf(fp, "%d\n", &N)) {
30             exit(EXIT_FAILURE);
31         }
32     }
33
34     if((A = allocate_2d(N, N)) == NULL) {
35         exit(EXIT_FAILURE);
36     }
37     if(parse_matrix_2d(fp, N, N, A) == NULL) {
38         exit(EXIT_FAILURE);
39     }
40
41
42     sec = timer();
43     for (k = 0; k < N - 1; k++)
44     {
45         for (i = k + 1; i < N; i++)
46         {
47             l = A[i * N + k] / A[k * N + k];
48             for (j = k; j < N; j++)
49             {
50                 A[i * N + j] = A[i * N + j] - l * A[k * N + j];
51             }
52         }
53     }
54     sec = timer();
55     printf("Calc Time: %lf\n", sec);
56
57     fp = fopen(argv[2], "w");
58     fprintf_matrix_2d(fp, N, N, A);
59     fclose(fp);
60     free(A);
61
62     return 0;
63 }

```

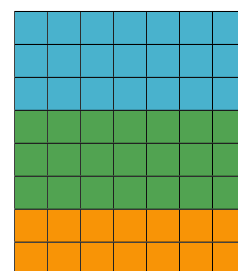
## Ζητούμενο 2 Παράλληλισμός Αλγορίθμου

Ο παράλληλισμός του αλγορίθμου εντοπίζεται στο γεγονός ότι υπάρχει ανεξαρτησία του υπολογισμού κατά γραμμές για δεδομένο  $k$ . Καθ' όλη την εκτέλεση του προγράμματος κρατάμε σταθερό τον τρόπο διαμοιρασμού των γραμμών του πίνακα, μοιράζοντας σε κάθε επανάληψη την  $k^{th}$  γραμμή.



...

*Circular*



*Continuous*

## Ζητούμενο 3 Μοντέλο κοινού χώρου διευθύνσεων (OpenMP)

## Ζητούμενο 4 Μοντέλο ανταλλαγής μηνυμάτων (MPI)

### Ζητούμενο 4.1 Point to Point

Η υλοποίηση **point-to-point** με χρήση flooding για λογαριθμικό propagation και κυκλική κατανομή των γραμμών (*Circular*).

```
1  /* .....
2  * File Name : main.c
3  * Creation Date : 30-10-2012
4  * Last Modified : Mon 12 Nov 2012 09:58:12 AM EET
5  * Created By : Greg Liras <gregliras@gmail.com>
6  * Created By : Alex Maurogiannis <nalfemp@gmail.com>
7  .....*/
8
9  #include <mpi.h>
10 #include <stdio.h>
11 #include <stdlib.h>
12 #include <signal.h>
13 #include <signal.h>
14 #include <unistd.h>
15 #include <string.h>
16
17 #include "common.h"
18
19 #define BLOCK_ROWS 1
20
21
22 void process_rows(int k, int rank, int N, int max_rank, double *A)
23 {
24     /*      performs the calculations for a given set of rows.
25     *      In this hybrid version each thread is assigned blocks of
26     *      continuous rows in a cyclic manner.
27     */
28     int i, j, w;
29     double l;
30     /* For every cyclic repetition of a block */
31     for (i = (rank + ((BLOCK_ROWS * max_rank) * (k / (BLOCK_ROWS * max_rank)))); \
32          i < N ; i+=(max_rank * BLOCK_ROWS)) {
33         if (i > k) {
34             /* Calculate each continuous row in the block*/
35             for (w = i; w < (i + BLOCK_ROWS) && w < (N * N); w++){
36                 l = A[(w * N) + k] / A[(k * N) + k];
37                 for (j = k; j < N; j++) {
38                     A[(w * N) + j] = A[(k * N) + j] - l * A[(k * N) + j];
39                 }
40             }
41         }
42     }
43 }
44
45 int main(int argc, char **argv)
46 {
47     int k;
48     int N;
49     int rank;
50     int max_rank;
51     int last_rank;
52     double *A = NULL;
53     double sec = 0;
54
55     int ret = 0;
56     FILE *fp = NULL;
57     usage(argc, argv);
58
59     MPI_Init(&argc, &argv);
60     MPI_Comm_rank(MPI_COMM_WORLD, &rank);
61     MPI_Comm_size(MPI_COMM_WORLD, &max_rank);
62
63     if (rank == 0) {
64         debug("rank: %d opens file: %s\n", rank, argv[1]);
65         fp = fopen(argv[1], "r");
66         if(fp) {
67             if(!fscanf(fp, "%d\n", &N)) {
68                 MPI_Abort(MPI_COMM_WORLD, 1);
69             }

```

```

70     }
71     else {
72         MPI_Abort(MPI_COMM_WORLD, 1);
73     }
74 }
75
76 MPI_Barrier(MPI_COMM_WORLD);
77 propagate_with_flooding(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
78
79 /* Everyone allocates the whole table */
80 debug("Max rank = %d\n", max_rank);
81 if((A = allocate_2d_with_padding(N, N, max_rank)) == NULL) {
82     MPI_Abort(MPI_COMM_WORLD, 1);
83 }
84 /* Root Parses file */
85 if (rank == 0) {
86     if(parse_matrix_2d(fp, N, N, A) == NULL) {
87         MPI_Abort(MPI_COMM_WORLD, 1);
88     }
89     fclose(fp);
90     fp = NULL;
91 }
92 /* And distributes the table */
93 MPI_Barrier(MPI_COMM_WORLD);
94 propagate_with_flooding(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
95
96 last_rank = (N - 1) % max_rank;
97
98 if(rank == 0) {
99     sec = timer();
100 }
101
102 for (k = 0; k < N - 1; k++) {
103     /* The owner of the row for this k broadcasts it*/
104     MPI_Barrier(MPI_COMM_WORLD);
105     propagate_with_flooding(&A[k * N], N, MPI_DOUBLE, \
106         ((k % (max_rank * BLOCK_ROWS)) / BLOCK_ROWS), MPI_COMM_WORLD);
107     process_rows(k, rank, N, max_rank, A);
108 }
109
110 MPI_Barrier(MPI_COMM_WORLD);
111 if (rank == 0) {
112     sec = timer();
113     printf("Calc Time: %lf\n", sec);
114 }
115 ret = MPI_Finalize();
116
117 if(ret == 0) {
118     debug("%d FINALIZED!!! with code: %d\n", rank, ret);
119 }
120 else {
121     debug("%d NOT FINALIZED!!! with code: %d\n", rank, ret);
122 }
123
124 /* Last process has table */
125 if (rank == last_rank) {
126     //print_matrix_2d(N, N, A);
127     fp = fopen(argv[2], "w");
128     fprintf_matrix_2d(fp, N, N, A);
129     fclose(fp);
130 }
131 free(A);
132
133 return 0;
134 }

```

Η υλοποίηση **point-to-point** με χρήση flooding για λογαριθμικό propagation και συνεχή κατανομή των γραμμών (*Continuous*).

```

1  /* -. -. -. -. -. -. -. -. -. -. -. -. -. -. -.
2  * File Name : main.c
3  * Creation Date : 30-10-2012
4  * Last Modified : Mon 12 Nov 2012 09:56:29 AM EET
5  * Created By : Greg Liras <gregliras@gmail.com>
6  * Created By : Alex Maurogiannis <nalfemp@gmail.com>

```

```

7  .....*/
8
9  #include <mpi.h>
10 #include <stdio.h>
11 #include <stdlib.h>
12 #include <signal.h>
13 #include <signal.h>
14 #include <unistd.h>
15 #include <string.h>
16
17 #include "common.h"
18
19
20 int get_bcaster(int *ccounts, int bcaster)
21 {
22     if (ccounts[bcaster]-- > 0 ){
23         return bcaster;
24     } else {
25         return bcaster+1;
26     }
27 }
28
29 void get_displs(int *counts, int max_rank, int *displs)
30 {
31     int j;
32     displs[0] = 0;
33     for (j = 1; j < max_rank ; j++) {
34         displs[j] = displs[j - 1] + counts[j - 1];
35     }
36 }
37
38 int max(int a, int b)
39 {
40     return a > b ? a : b;
41 }
42
43 void process_rows(int k, int rank, int N, int max_rank, int block_rows, int *displs, double *A)
44 {
45     /*      performs the calculations for a given set of rows.
46      *      In this hybrid version each thread is assigned blocks of
47      *      continuous rows in a cyclic manner.
48      */
49     int j, w;
50     double l;
51     int start = max(displs[rank], k+1);
52     for (w = start; w < (start + block_rows) && w < N; w++){
53         l = A[(w * N) + k] / A[(k * N) + k];
54         for (j = k; j < N; j++) {
55             A[(w * N) + j] = A[(k * N) + j] - l * A[(k * N) + j];
56         }
57     }
58 }
59
60 /* distributes the rows in a continuous fashion */
61 void distribute_rows(int max_rank, int N, int *counts)
62 {
63     int j, k;
64     int rows = N;
65
66     /* Initialize counts */
67     for (j = 0; j < max_rank ; j++) {
68         counts[j] = (rows / max_rank);
69     }
70
71     /* Distribute the indivisible leftover */
72     if (rows / max_rank != 0) {
73         j = rows % max_rank;
74         for (k = 0; k < max_rank && j > 0; k++, j--) {
75             counts[k] += 1;
76         }
77     } else {
78         for (k = 0; k < max_rank; k++){
79             counts[k] = 1;
80         }
81     }

```



```

82 }
83
84
85
86 int main(int argc, char **argv)
87 {
88     int i, j, k;
89     int N;
90     int rank;
91     int max_rank;
92     int block_rows;
93     int *counts;
94     int *displs;
95     int *ccounts;
96     int ret = 0;
97     int bcaster = 0;
98     double l;
99     double sec;
100     double *A = NULL;
101     FILE *fp = NULL;
102
103
104     usage(argc, argv);
105
106     MPI_Init(&argc, &argv);
107     MPI_Comm_rank(MPI_COMM_WORLD, &rank);
108     MPI_Comm_size(MPI_COMM_WORLD, &max_rank);
109
110     if (rank == 0) {
111         debug("rank: %d opens file: %s\n", rank, argv[1]);
112         fp = fopen(argv[1], "r");
113         if(fp) {
114             if(!fscanf(fp, "%d\n", &N)) {
115                 MPI_Abort(MPI_COMM_WORLD, 1);
116             }
117         }
118         else {
119             MPI_Abort(MPI_COMM_WORLD, 1);
120         }
121     }
122
123     MPI_Barrier(MPI_COMM_WORLD);
124     propagate_with_flooding(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
125
126     counts = malloc(max_rank * sizeof(int));
127     displs = malloc(max_rank * sizeof(int));
128     ccounts = malloc(max_rank * sizeof(int));
129
130     distribute_rows(max_rank, N, counts);
131     get_displs(counts, max_rank, displs);
132     memcpy(ccounts, counts, max_rank * sizeof(int));
133
134     #if main_DEBUG
135     printf("CCounts is :\n");
136     for (j = 0; j < max_rank ; j++) {
137         printf("%d\n", ccounts[j]);
138     }
139     #endif
140
141     /* Everybody Allocates the whole table */
142     if((A = allocate_2d_with_padding(N, N, max_rank)) == NULL) {
143         MPI_Abort(MPI_COMM_WORLD, 1);
144     }
145     if (rank == 0) {
146         if(parse_matrix_2d(fp, N, N, A) == NULL) {
147             MPI_Abort(MPI_COMM_WORLD, 1);
148         }
149         fclose(fp);
150         fp = NULL;
151     }
152
153     MPI_Barrier(MPI_COMM_WORLD);
154     propagate_with_flooding(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
155
156     /* Start Timing */

```



```

30  /* For every cyclic repetition of a block */
31  for (i = (rank + ((BLOCK_ROWS * max_rank) * (k / (BLOCK_ROWS * max_rank)))); i < N ; i+=(max_rank * BLOCK_ROWS)) {
32      if (i > k) {
33          /* Calculate each continuous row in the block*/
34          for (w = i; w < (i + BLOCK_ROWS) && w < (N * N); w++){
35              l = A[(w * N) + k] / A[(k * N) + k];
36              for (j = k; j < N; j++) {
37                  A[(w * N) + j] = A[(w * N) + j] - l * A[(k * N) + j];
38              }
39          }
40      }
41  }
42  }
43
44  int main(int argc, char **argv)
45  {
46      int k;
47      int N;
48      int rank;
49      int max_rank;
50      int last_rank;
51      double *A = NULL;
52      double sec = 0;
53
54      int ret = 0;
55      FILE *fp = NULL;
56      usage(argc, argv);
57
58      MPI_Init(&argc, &argv);
59      MPI_Comm_rank(MPI_COMM_WORLD, &rank);
60      MPI_Comm_size(MPI_COMM_WORLD, &max_rank);
61
62      if (rank == 0) {
63          debug("rank: %d opens file: %s\n", rank, argv[1]);
64          fp = fopen(argv[1], "r");
65          if(fp) {
66              if(!fscanf(fp, "%d\n", &N)) {
67                  MPI_Abort(MPI_COMM_WORLD, 1);
68              }
69          }
70          else {
71              MPI_Abort(MPI_COMM_WORLD, 1);
72          }
73      }
74
75
76      MPI_Barrier(MPI_COMM_WORLD);
77      MPI_Bcast(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
78
79      /* Everyone allocates the whole table */
80      debug("Max rank = %d\n", max_rank);
81      if((A = allocate_2d_with_padding(N, N, max_rank)) == NULL) {
82          MPI_Abort(MPI_COMM_WORLD, 1);
83      }
84      /* Root Parses file */
85      if (rank == 0) {
86          if(parse_matrix_2d(fp, N, N, A) == NULL) {
87              MPI_Abort(MPI_COMM_WORLD, 1);
88          }
89          fclose(fp);
90          fp = NULL;
91      }
92      /* And distributes the table */
93      MPI_Barrier(MPI_COMM_WORLD);
94      MPI_Bcast(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
95
96      last_rank = (N - 1) % max_rank;
97
98      if(rank == 0) {
99          sec = timer();
100      }
101
102      for (k = 0; k < N - 1; k++) {
103          /* The owner of the row for this k broadcasts it*/
104          MPI_Barrier(MPI_COMM_WORLD);

```

```

105     MPI_Bcast(&A[k * N], N, MPI_DOUBLE, ((k % (max_rank * BLOCK_ROWS)) / BLOCK_ROWS), MPI_COMM_WORLD);
106
107     process_rows(k, rank, N, max_rank, A);
108 }
109
110 MPI_Barrier(MPI_COMM_WORLD);
111 if (rank == 0) {
112     sec = timer();
113     printf("Calc Time: %lf\n", sec);
114 }
115 ret = MPI_Finalize();
116
117 if (ret == 0) {
118     debug("%d FINALIZED!!! with code: %d\n", rank, ret);
119 }
120 else {
121     debug("%d NOT FINALIZED!!! with code: %d\n", rank, ret);
122 }
123
124 /* Last process has table */
125 if (rank == last_rank) {
126     //print_matrix_2d(N, N, A);
127     fp = fopen(argv[2], "w");
128     fprintf_matrix_2d(fp, N, N, A);
129     fclose(fp);
130 }
131 free(A);
132
133 return 0;
134 }

```

H collective υλοποίηση για συνεχή κατανομή των γραμμών (*Continuous*).

```

1  /* -.-.-.-.-.
2  * File Name : main.c
3  * Creation Date : 30-10-2012
4  * Last Modified : Mon 12 Nov 2012 10:03:03 AM EET
5  * Created By : Greg Liras <greyliras@gmail.com>
6  * Created By : Alex Maurogiannis <nalfemp@gmail.com>
7  -.-.-.-.-.*/
8
9  #include <mpi.h>
10 #include <stdio.h>
11 #include <stdlib.h>
12 #include <signal.h>
13 #include <unistd.h>
14 #include <string.h>
15
16
17 #include "common.h"
18
19
20 int get_bcaster(int *ccounts, int bcaster)
21 {
22     if (ccounts[bcaster]-- > 0 ){
23         return bcaster;
24     }
25     else {
26         return bcaster+1;
27     }
28 }
29
30 void get_displs(int *ccounts, int max_rank, int *displs)
31 {
32     int j;
33     displs[0] = 0;
34     for (j = 1; j < max_rank ; j++) {
35         displs[j] = displs[j - 1] + ccounts[j - 1];
36     }
37 }
38
39 int max(int a, int b)
40 {
41     return a > b ? a : b;
42 }
43

```

```

44 void process_rows(int k, int rank, int N, int max_rank, int block_rows, int *displs, double *A)
45 {
46     /*      performs the calculations for a given set of rows.
47      *      In this hybrid version each thread is assigned blocks of
48      *      continuous rows in a cyclic manner.
49      */
50     int j, w;
51     double l;
52     int start = max(displs[rank], k+1);
53     for (w = start; w < (start + block_rows) && w < N; w++){
54         l = A[(w * N) + k] / A[(k * N) + k];
55         for (j = k; j < N; j++) {
56             A[(w * N) + j] = A[(w * N) + j] - l * A[(k * N) + j];
57         }
58     }
59 }
60
61 /* distributes the rows in a continuous fashion */
62 void distribute_rows(int max_rank, int N, int *counts)
63 {
64     int j, k;
65     int rows = N;
66
67     /* Initialize counts */
68     for (j = 0; j < max_rank ; j++) {
69         counts[j] = (rows / max_rank);
70     }
71
72     /* Distribute the indivisible leftover */
73     if (rows / max_rank != 0) {
74         j = rows % max_rank;
75         for (k = 0; k < max_rank && j > 0; k++, j--) {
76             counts[k] += 1;
77         }
78     }
79     else {
80         for (k = 0; k < max_rank; k++) {
81             counts[k] = 1;
82         }
83     }
84 }
85
86
87
88 int main(int argc, char **argv)
89 {
90     int i, j, k;
91     int N;
92     int rank;
93     int max_rank;
94     int block_rows;
95     int *counts;
96     int *displs;
97     int *ccounts;
98     int ret = 0;
99     int bcaster = 0;
100     double l;
101     double sec;
102     double *A = NULL;
103     FILE *fp = NULL;
104
105
106     usage(argc, argv);
107
108     MPI_Init(&argc, &argv);
109     MPI_Comm_rank(MPI_COMM_WORLD, &rank);
110     MPI_Comm_size(MPI_COMM_WORLD, &max_rank);
111
112     if (rank == 0) {
113         debug("rank: %d opens file: %s\n", rank, argv[1]);
114         fp = fopen(argv[1], "r");
115         if(fp) {
116             if(!fscanf(fp, "%d\n", &N)) {
117                 MPI_Abort(MPI_COMM_WORLD, 1);
118             }

```

```

119     }
120     else {
121         MPI_Abort(MPI_COMM_WORLD, 1);
122     }
123
124 }
125
126 MPI_Barrier(MPI_COMM_WORLD);
127 MPI_Bcast(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
128
129 counts = malloc(max_rank * sizeof(int));
130 displs = malloc(max_rank * sizeof(int));
131 ccounts = malloc(max_rank * sizeof(int));
132
133 distribute_rows(max_rank, N, counts);
134 get_displs(counts, max_rank, displs);
135 memcpy(ccounts, counts, max_rank * sizeof(int));
136
137 #if main_DEBUG
138 printf("CCounts is :\n");
139 for (j = 0; j < max_rank ; j++) {
140     printf("%d\n", ccounts[j]);
141 }
142 #endif
143
144 /* Everybody Allocates the whole table */
145 if((A = allocate_2d_with_padding(N, N, max_rank)) == NULL) {
146     MPI_Abort(MPI_COMM_WORLD, 1);
147 }
148 if (rank == 0) {
149     if(parse_matrix_2d(fp, N, N, A) == NULL) {
150         MPI_Abort(MPI_COMM_WORLD, 1);
151     }
152     fclose(fp);
153     fp = NULL;
154 }
155
156 MPI_Barrier(MPI_COMM_WORLD);
157 MPI_Bcast(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
158
159 /* Start Timing */
160 if(rank == 0) {
161     sec = timer();
162 }
163
164
165 for (k = 0; k < N - 1; k++) {
166     block_rows = counts[rank];
167     bcaster = get_bcaster(ccounts, bcaster);
168
169     MPI_Barrier(MPI_COMM_WORLD);
170     debug(" broadcaster is %d\n", bcaster);
171     MPI_Barrier(MPI_COMM_WORLD);
172     MPI_Bcast(&A[k * N], N, MPI_DOUBLE, bcaster, MPI_COMM_WORLD);
173
174     process_rows(k, rank, N, max_rank, block_rows, displs, A);
175 }
176
177 MPI_Barrier(MPI_COMM_WORLD);
178 if(rank == 0) {
179     sec = timer();
180     printf("Calc Time: %lf\n", sec);
181 }
182 ret = MPI_Finalize();
183
184 if(ret == 0) {
185     debug("%d FINALIZED!!! with code: %d\n", rank, ret);
186 }
187 else {
188     debug("%d NOT FINALIZED!!! with code: %d\n", rank, ret);
189 }
190
191 if(rank == (max_rank - 1)) {
192     fp = fopen(argv[2], "w");
193     fprintf_matrix_2d(fp, N, N, A);

```

```
194         fclose(fp);
195     }
196     free(A);
197     free(counts);
198     free(ccounts);
199
200     return 0;
201 }
```