



ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

ΣΧΟΛΗ ΗΜ&ΜΥ

Συστήματα Παράλληλης Επεξεργασίας 1^η Άσκηση
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Ομάδα 8^η

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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 09:04:50 PM 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
26 double *allocate_2d(int N, int M);
27 double *allocate_2d_with_padding(int N, int M, int max_rank);
28 double *parse_matrix_2d(FILE *fp, int N, int M, double *A);
29 void fprintf_matrix_2d(FILE *fp, int N, int M, double *A);
30 void print_matrix_2d(int N, int M, double *A);
31 double timer(void);
32 void usage(int argc, char **argv);
33
34 #ifdef USE_MPI /* USE_MPI */
35 #include <mpi.h>
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 */
43
44
45 1  /* -.-.-.-.-.
46 2  * File Name : common.c
47 3  * Creation Date : 06-11-2012
48 4  * Last Modified : Mon 12 Nov 2012 10:06:02 AM EET
49 5  * Created By : Greg Liras <gregliras@gmail.com>
50 6  * Created By : Alex Maurogiannis <nalfemp@gmail.com>
51 7  -.-.-.-.-.*/
52 8
53 9  #include "common.h"
54 10 #include <sys/time.h>
55 11
56 12 double *allocate_2d(int N, int M)
57 13 {
58 14     double *A;
59 15     A = malloc(N * M * sizeof(double));
60 16     return A;
61 17 }
62 18
63 19 double *allocate_2d_with_padding(int N, int M, int max_rank)
64 20 {
65 21     double *A;
66 22     A = allocate_2d(N + max_rank, M);
67 23     return A;
68 24 }
69 25
70 26 double *parse_matrix_2d(FILE *fp, int N, int M, double *A)
71 27 {
72 28     int i,j;
73 29     double *p;
74 30     p = A;
75 31     for (i = 0; i < N; i++) {
76 32         for (j = 0; j < M; j++) {
77 33             if(!fscanf(fp, "%lf", p++)) {
78 34                 return NULL;
79 35             }
80 36         }
81 37     }
82 38     return A;
83 39 }
84 40
85 41 void fprintf_matrix_2d(FILE *fp, int N, int M, double *A)
86 42 {
87 43     for (i = 0; i < N; i++) {
88 44         for (j = 0; j < M; j++) {
89 45             fprintf(fp, "%lf ", A[i*M+j]);
90 46         }
91 47         fprintf(fp, "\n");
92 48     }
93 49 }
```

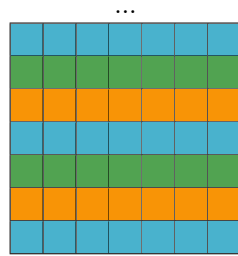
```

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(rank != 0) {
130         if(rank == root) {
131             MPI_Send(buffer, count, datatype, 0, root, comm);

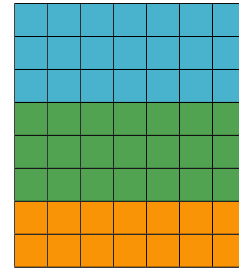
```


Ζητούμενο 2 Παραλληλισμός Αλγορίθμου

Ο παραλληλισμός 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 διαμοίρασμού των γραμμών του πίνακα, μοιράζοντας σε κάθε επανάληψη την k^{th} γραμμή.



Circular



Continuous

Ζητούμενο 3 Μοντέλο κοινού χώρου διευθύνσεων (OpenMP)

Η υλοποίηση μοντέλου κοινού χώρου διευθύνσεων βασίζεται στην δομή `pragma omp for`, με χρήση `private` μεταβλητών `divisor` και `A2` για κάθε thread ώστε να αποφεύγονται όσο γίνεται οι προσβάσεις στην κοινή μνήμη. Επιπλέον, έχουν πραγματοποιηθεί βελτιστοποιήσεις μέσω flags του gcc, όπως φαίνεται στο Makefile.

```
1  /* .....
2  * File Name : main.c
3  * Creation Date : 30-10-2012
4  * Last Modified : Mon 12 Nov 2012 08:54:16 PM 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 #include <omp.h>
12
13
14 #include "common.h"
15
16 int main(int argc, char **argv)
17 {
18     int i,j,k;
19     int N;
20     double *A;
21     double l;
22     double sec;
23
24     FILE *fp = NULL;
25     usage(argc, argv);
26     /*
27      * Allocate me!
28      */
29     fp = fopen(argv[1], "r");
30     if(fp) {
31         if(!fscanf(fp, "%d\n", &N)) {
32             exit(EXIT_FAILURE);
33         }
34     }
35
36     if((A = allocate_2d(N, N)) == NULL) {
37         exit(EXIT_FAILURE);
38     }
39     if(parse_matrix_2d(fp, N, N, A) == NULL) {
40         exit(EXIT_FAILURE);
41     }
42
43
44     int chunk = N/omp_get_max_threads();
45     double divisor;
46     double *A2;
47     chunk = 1;
48
49     sec = timer();
50
51     for (k = 0; k < N - 1; k++)
52     {
53         #pragma omp parallel private(divisor)
54         {
55             divisor = A[k * N + k];
56             #pragma omp for schedule(static, chunk) private(l, j, A2)
57             for (i = k + 1; i < N; i++)
```

```

58         {
59             A2 = &A[i * N];
60
61             l = A2[k] / divisor;
62             for (j = k; j < N; j++)
63             {
64                 A2[j] = A2[j] - l * A[k * N + j];
65             }
66         }
67     }
68 }
69 sec = timer();
70 printf("Calc Time: %lf\n", sec);
71
72 fp = fopen(argv[2], "w");
73 fprintf_matrix_2d(fp, N, N, A);
74 fclose(fp);
75 free(A);
76
77 return 0;
78 }

```

```

1 TARGET = main
2 CC = gcc
3 CFLAGS +=
4 OPTCFLAGS+= -march=native -O3 -fexpensive-optimizations -funroll-loops \
5             -fmove-loop-invariants -fprefetch-loop-arrays -ftree-loop-optimize \
6             -ftree-vect-loop-version -ftree-vectorize
7 LDFLAGS += -fopenmp
8 OPT = 2
9
10 ifndef DEBUG
11     DEBUG = n
12 endif
13
14 ifeq ($(DEBUG),y)
15     CFLAGS += -D$(TARGET)_DEBUG=1
16     CFLAGS += -g -O0 -Werror -Wall -Wextra -Wuninitialized
17     LDFLAGS += -lefence
18 else
19     CFLAGS += -D$(TARGET)_DEBUG=0
20     CFLAGS += -Werror -Wall
21     CFLAGS += $(OPTCFLAGS)
22 endif
23
24 CCFILES += $(wildcard *.c)
25 OBJ += $(patsubst %.c,%.o,$(CCFILES))
26 DEPENDS += $(wildcard *.h)
27
28
29 all: $(TARGET).exec
30
31 $(TARGET).exec: $(OBJ) $(DEPENDS)
32     $(CC) $(LDFLAGS) $(OBJ) -o $(TARGET).exec
33
34 %.o: %.c
35     $(CC) -c $(LDFLAGS) $(CFLAGS) $< -o $@
36
37
38 .PHONY: clean all indent tags
39 clean:
40     rm -f $(OBJ) $(TARGET)
41 indent:
42     astyle --style=linux $(CCFILES)
43 tags:
44     ctags -R *

```

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 01:25:21 PM 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[(w * 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(N, N)) == 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 01:34:38 PM 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 *ccounts, 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     */
47     int j, w;
48     double l;
49     int start = max(displs[rank], k+1);
50     for (w = start; w < (start + block_rows) && w < N; w++){
51         l = A[(w * N) + k] / A[(k * N) + k];
52         for (j = k; j < N; j++) {
53             A[(w * N) + j] = A[(w * N) + j] - l * A[(k * N) + j];
54         }
55     }
56 }
57
58 /* distributes the rows in a continuous fashion */
59 void distribute_rows(int max_rank, int N, int *counts)
60 {
61     int j, k;
62     int rows = N;
63
64     /* Initialize counts */
65     for (j = 0; j < max_rank ; j++) {
66         counts[j] = (rows / max_rank);
67     }
68
69     /* Distribute the indivisible leftover */
70     if (rows / max_rank != 0) {
71         j = rows % max_rank;
72         for (k = 0; k < max_rank && j > 0; k++, j--) {
73             counts[k] += 1;
74         }
75     } else {
76         for (k = 0; k < max_rank; k++){
77             counts[k] = 1;
78         }
79     }
80 }
81
82
83
84 int main(int argc, char **argv)
85 {
86     int k;
87     int N;
88     int rank;
89     int max_rank;
90     int block_rows;
91     int *counts;
92     int *displs;
93     int *ccounts;
94     int ret = 0;
95     int bcaster = 0;
96     double sec;
97     double *A = NULL;
98     FILE *fp = NULL;
99
100
101     usage(argc, argv);
102
103     MPI_Init(&argc, &argv);
104     MPI_Comm_rank(MPI_COMM_WORLD, &rank);
105     MPI_Comm_size(MPI_COMM_WORLD, &max_rank);
106
107     if(rank == 0) {
108         debug("rank: %d opens file: %s\n", rank, argv[1]);
109         fp = fopen(argv[1], "r");
110         if(fp) {
111             if(!fscanf(fp, "%d\n", &N)) {
112                 MPI_Abort(MPI_COMM_WORLD, 1);
113             }
114         }
115         else {
116             MPI_Abort(MPI_COMM_WORLD, 1);
117         }
118     }
119 }
120

```

```

121 MPI_Barrier(MPI_COMM_WORLD);
122 propagate_with_flooding(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
123
124 counts = malloc(max_rank * sizeof(int));
125 displs = malloc(max_rank * sizeof(int));
126 ccunts = malloc(max_rank * sizeof(int));
127
128 distribute_rows(max_rank, N, counts);
129 get_displs(counts, max_rank, displs);
130 memcpy(ccunts, counts, max_rank * sizeof(int));
131
132 #if main_DEBUG
133 printf("CCounts is :\n");
134 for (j = 0; j < max_rank ; j++) {
135     printf("%d\n", ccunts[j]);
136 }
137 #endif
138
139 /* Everybody Allocates the whole table */
140 if((A = allocate_2d(N, N)) == NULL) {
141     MPI_Abort(MPI_COMM_WORLD, 1);
142 }
143 if(rank == 0) {
144     if(parse_matrix_2d(fp, N, N, A) == NULL) {
145         MPI_Abort(MPI_COMM_WORLD, 1);
146     }
147     fclose(fp);
148     fp = NULL;
149 }
150
151 MPI_Barrier(MPI_COMM_WORLD);
152 propagate_with_flooding(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
153
154 block_rows = counts[rank];
155
156 /* Start Timing */
157 if(rank == 0) {
158     sec = timer();
159 }
160
161 for (k = 0; k < N - 1; k++) {
162     bcaster = get_bcaster(ccunts, bcaster);
163
164     debug(" broadcaster is %d\n", bcaster);
165     MPI_Barrier(MPI_COMM_WORLD);
166     propagate_with_flooding(&A[k * N], N, MPI_DOUBLE, bcaster, MPI_COMM_WORLD);
167
168     process_rows(k, rank, N, max_rank, block_rows, displs, A);
169 }
170
171 MPI_Barrier(MPI_COMM_WORLD);
172 if(rank == 0) {
173     sec = timer();
174     printf("Calc Time: %lf\n", sec);
175 }
176 ret = MPI_Finalize();
177
178 if(ret == 0) {
179     debug("%d FINALIZED!!! with code: %d\n", rank, ret);
180 }
181 else {
182     debug("%d NOT FINALIZED!!! with code: %d\n", rank, ret);
183 }
184
185 if(rank == (max_rank - 1)) {
186     fp = fopen(argv[2], "w");
187     fprintf_matrix_2d(fp, N, N, A);
188     fclose(fp);
189 }
190 free(A);
191 free(counts);
192 free(ccunts);
193 free(displs);
194
195 return 0;
196 }

```

Ζητούμενο 4.2 Collective

H collective υλοποίηση για κυκλική κατανομή των γραμμών (*Circular*).

```

1  /* -.-.-.-.-
2  * File Name : main.c
3  * Creation Date : 30-10-2012
4  * Last Modified : Mon 12 Nov 2012 01:25:30 PM 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)))); 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     MPI_Barrier(MPI_COMM_WORLD);
76     MPI_Bcast(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
77
78     /* Everyone allocates the whole table */
79     debug("Max rank = %d\n", max_rank);
80     if ((A = allocate_2d(N, N)) == NULL) {
81         MPI_Abort(MPI_COMM_WORLD, 1);
82     }
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
93     /* And distributes the table */
94     MPI_Barrier(MPI_COMM_WORLD);
95     MPI_Bcast(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
96
97     last_rank = (N - 1) % max_rank;

```



```

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 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 sec;
101    double *A = NULL;
102    FILE *fp = NULL;
103
104
105    usage(argc, argv);
106
107    MPI_Init(&argc, &argv);
108    MPI_Comm_rank(MPI_COMM_WORLD, &rank);
109    MPI_Comm_size(MPI_COMM_WORLD, &max_rank);
110
111    if (rank == 0) {
112        debug("rank: %d opens file: %s\n", rank, argv[1]);
113        fp = fopen(argv[1], "r");
114        if (fp) {
115            if (!fscanf(fp, "%d\n", &N)) {
116                MPI_Abort(MPI_COMM_WORLD, 1);
117            }
118        }
119        else {
120            MPI_Abort(MPI_COMM_WORLD, 1);
121        }
122    }
123
124
125    MPI_Barrier(MPI_COMM_WORLD);
126    MPI_Bcast(&N, 1, MPI_INT, 0, MPI_COMM_WORLD);
127
128    counts = malloc(max_rank * sizeof(int));
129    displs = malloc(max_rank * sizeof(int));
130    ccounts = malloc(max_rank * sizeof(int));
131
132    distribute_rows(max_rank, N, counts);
133    get_displs(counts, max_rank, displs);
134    memcpy(ccounts, counts, max_rank * sizeof(int));
135
136    #if main_DEBUG
137    printf("CCounts is :\n");

```

```

138     for (j = 0; j < max_rank ; j++) {
139         printf("%d\n", ccounts[j]);
140     }
141 #endif
142
143     /* Everybody Allocates the whole table */
144     if((A = allocate_2d(N, N)) == NULL) {
145         MPI_Abort(MPI_COMM_WORLD, 1);
146     }
147     if (rank == 0) {
148         if(parse_matrix_2d(fp, N, N, A) == NULL) {
149             MPI_Abort(MPI_COMM_WORLD, 1);
150         }
151         fclose(fp);
152         fp = NULL;
153     }
154
155     MPI_Barrier(MPI_COMM_WORLD);
156     MPI_Bcast(A, N*N, MPI_DOUBLE, 0, MPI_COMM_WORLD);
157
158     /* Start Timing */
159     if(rank == 0) {
160         sec = timer();
161     }
162
163
164     for (k = 0; k < N - 1; k++) {
165         block_rows = counts[rank];
166         bcaster = get_bcaster(ccounts, bcaster);
167
168         MPI_Barrier(MPI_COMM_WORLD);
169         debug(" broadcaster is %d\n", bcaster);
170         MPI_Barrier(MPI_COMM_WORLD);
171         MPI_Bcast(&A[k * N], N, MPI_DOUBLE, bcaster, MPI_COMM_WORLD);
172
173         process_rows(k, rank, N, max_rank, block_rows, displs, A);
174     }
175
176     MPI_Barrier(MPI_COMM_WORLD);
177     if(rank == 0) {
178         sec = timer();
179         printf("Calc Time: %lf\n", sec);
180     }
181     ret = MPI_Finalize();
182
183     if(ret == 0) {
184         debug("%d FINALIZED!!! with code: %d\n", rank, ret);
185     }
186     else {
187         debug("%d NOT FINALIZED!!! with code: %d\n", rank, ret);
188     }
189
190     if(rank == (max_rank - 1)) {
191         fp = fopen(argv[2], "w");
192         fprintf_matrix_2d(fp, N, N, A);
193         fclose(fp);
194     }
195     free(A);
196     free(counts);
197     free(ccounts);
198
199     return 0;
200 }

```