High Performance Computing (COCSC18)

Practical Lab File

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COE-I

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1. Run a basic hello world program using pThreads.

Code:

```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
int thread_count; // this global variable is shared by all threads
// compiling information -
// gcc name_of_file.c -o name_of_exe -lpthread (link p thread)
// this function is what we want to parallelize
void *Hello(void *rank);

// main driver function of the program
int main(int argc, char *argv[])
{
   long thread;
   // /* Use long in case of a 64−bit system */

   pthread_t *thread_handles;
   // /* Get number of threads from command line */
   // since the command line arg would be string,
   // we convert to the long value

   thread_count = strtol(argv[1], NULL, 10);
   // get the thread handles equal to total num of threads

   thread_handles = malloc(thread_count * sizeof(pthread_t));
   // note : we need to manually startup our threads
   // for a particular function which we want to execute in
   // the thread
   // void* is a pretty nice concept,
   // it is essentially a pointer to
   // ANY type of memory,3
   // you just dereference it with the type you expect
   // it to be

   for (thread = 0; thread < thread_count; thread++)
      pthread_create(&thread_handles[thread], NULL, Hello, (void *)thread);

   // Thread placement on cores is done by OS
   printf("Hello from the main thread\n");

   for (thread = 0; thread < thread_count; thread++)
      pthread_join(thread_handles[thread], NULL);

   free(thread_handles);
   return 0;
}

// /* main */
void *Hello(void *rank) // void * means a pointer, can be of any type
```

```
{
   // Each thread has its own stack
   // note : local variables of a thread are
   // private to the thread and each thread
   // will have its own local copy

   long my_rank = (long)rank;
   // /* Use long in case of 64-bit system */

   printf("Hello from thread %ld of %d\n", my_rank, thread_count);
   return NULL;
}
```

Output

```
kaushal@kaushal-VirtualBox:~/hpc$ touch helloworld.c
kaushal@kaushal-VirtualBox:~/hpc$ gcc helloworld.c -o helloworld -lpthread
kaushal@kaushal-VirtualBox:~/hpc$ ./helloworld 5
Hello from the main thread
Hello from thread 2 of 5
Hello from thread 1 of 5
Hello from thread 3 of 5
Hello from thread 4 of 5
Hello from thread 0 of 5
```

2.) Run a program to find the sum of all elements of an array using 2 processors.

Code

```
#include <mpi.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
// it is a message passing interface
// processes live inside a COMM_WORLD
// processes are LIVING, and exist in a COMMUNICATOR

int main(int argc, char **argv)
{
   // start the MPI code
   MPI_Init(NULL, NULL);
   int num_procs; // to store the size of the world / num of procs
   MPI_Comm_size(MPI_COMM_WORLD, &num_procs);
   int rank;
   MPI_Comm_rank(MPI_COMM_WORLD, &rank);
   if (rank == 0)
   {
      // read the array
      int n;
      // printf("Enter number of elements : ");
      scanf("%d", &n);
      int arr[n];
      for (int i = 0; i < n; i++)
      {
         arr[i] = rand() % 10000 + 1;
      }
      printf("Array is -\n [ ");
      for (int i = 0; i < n; i++)
      {
         printf("%d ", arr[i]);
      }
      printf("]\n");
      int elem_to_send = n / 2;
      if (n % 2)
         elem_to_send++;
      // send the size
      MPI_Send(&elem_to_send, 1, MPI_INT, 1, 0, MPI_COMM_WORLD);
      // send the array
      MPI_Send(&arr[n / 2], elem_to_send, MPI_INT, 1, 1, MPI_COMM_WORLD);
      float t1 = clock();
      int local = 0;
      for (int i = 0; i < n / 2; i++)
         local = local + arr[i];
      int s_rec = 0;
      float t2 = clock();
```

```
    printf("Time taken by process %d : %f\n", rank, (t2 - t1) / CLOCKS_PER_SEC);
    // recv the data into the local var s_rec
    MPI_Recv(&s_rec, 1, MPI_INT, 1, 2, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
    local = local + s_rec;
    printf("Total sum of array is %d\n", local);
  }
  else
  {
    // recieve the size of elements
    float t1 = clock();
    int size;
    MPI_Recv(&size, 1, MPI_INT, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);

    int arr[size];
    MPI_Recv(arr, size, MPI_INT, 0, 1, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
    float t2 = clock();
    printf("Total time for recieving : %f", (t2 - t1) / CLOCKS_PER_SEC);
    // lol, the time for recieving the elements is a thousand times slower
    // than the processing, lol waste
    t1 = clock();
    int local = 0;
    for (int i = 0; i < size; i++)
      local = local + arr[i];
    printf("\nProcess %d sending sum %d back to main...\n", rank, local);
    t2 = clock();
    printf("Time taken by process for addition %d : %f\n", rank, (t2 - t1) / CLOCKS_PER_SEC);
    MPI_Send(&local, 1, MPI_INT, 0, 2, MPI_COMM_WORLD);
  }
  MPI_Finalize();
}
```

Output

```
kaushal@kaushal-VirtualBox:~/hpc$ mpirun -np 2 ./add
55
Array is -
 [ 9384 887 2778 6916 7794 8336 5387 493 6650 1422 2363 28 8691 60 7764 3927 54
1 3427 9173 5737 5212 5369 2568 6430 5783 1531 2863 5124 4068 3136 3930 9803 40
23 3059 3070 8168 1394 8457 5012 8043 6230 7374 4422 4920 3785 8538 5199 4325 8
316 4371 6414 3527 6092 8981 9957 ]
Time taken by process 0 : 0.000002
Total sum of array is 281252
Total time for recieving : 1.968700
Process 1 sending sum 159738 back to main...
Time taken by process for addition 1 : 0.000010
```

3.) Compute the sum of all the elements of an array using p processors.

Code:

```
#include <mpi.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
int main(int argc, char **argv)
{
   // start the MPI code
   MPI_Init(NULL, NULL);
   int num_procs;
   MPI_Comm_size(MPI_COMM_WORLD, &num_procs);
   int rank;
   MPI_Comm_rank(MPI_COMM_WORLD, &rank);
   if (rank == 0)
   {
      // read the array
      int n;
      printf("Enter number of elements : ");
      scanf("%d", &n);
      int arr[n];
      for (int i = 0; i < n; i++)
      {
         arr[i] = rand() % 10 + 1;
      }
      printf("Array is -\n [ ");
      for (int i = 0; i < n; i++)
      {
         printf("%d ", arr[i]);
      }
      printf("]\n");
      int elem_to_send = n / num_procs;

      int tag = 0;
      for (int i = 1; i < num_procs; i++)
      { // send the size
         if (i != num_procs - 1)
         {
            elem_to_send = n / num_procs;
            MPI_Send(&elem_to_send, 1, MPI_INT, i, i + num_procs, MPI_COMM_WORLD);
            MPI_Send(&arr[i * (elem_to_send)], elem_to_send, MPI_INT, i, i + num_procs

                                                  + 1,
                  MPI_COMM_WORLD);
            continue;
         }
         // elements would be changed
         elem_to_send = n / num_procs + n % num_procs;
```

```
        MPI_Send(&elem_to_send, 1, MPI_INT, i, i + num_procs, MPI_COMM_WORLD);
        MPI_Send(&arr[(num_procs - 1) * (n / num_procs)], elem_to_send, MPI_INT, i, i +

                                                          num_procs + 1,
              MPI_COMM_WORLD);
        // send the array
      }
      int ans = 0;
      for (int i = 0; i < n / num_procs; i++)
        ans += arr[i];
      // recv the data into the local var s_rec
      int s_rec;
      for (int i = 1; i < num_procs; i++)
      {
        s_rec = 0;
        MPI_Recv(&s_rec, 1, MPI_INT, i, i + num_procs + 2, MPI_COMM_WORLD,

              MPI_STATUS_IGNORE);
        ans += s_rec;
      }
      printf("Total sum of array is %d\n", ans);
    }
    else
    {
      // receive the size of elements
      int size;
      MPI_Recv(&size, 1, MPI_INT, 0, rank + num_procs, MPI_COMM_WORLD,
            MPI_STATUS_IGNORE);

      int arr[size];
      MPI_Recv(arr, size, MPI_INT, 0, rank + num_procs + 1, MPI_COMM_WORLD,
            MPI_STATUS_IGNORE);
      int local = 0;
      for (int i = 0; i < size; i++)
        local = local + arr[i];
      printf("\nProcess %d sending sum %d back to main...\n", rank, local);
      MPI_Send(&local, 1, MPI_INT, 0, rank + num_procs + 2, MPI_COMM_WORLD);
    }
    MPI_Finalize();
}
```

Output

```
kaushal@kaushal-VirtualBox:~/hpc$ mpirun -np 2 ./sum_arr_p
220
Enter number of elements : Array is -
 [ 4 7 8 6 4 6 7 3 10 2 3 8 1 10 4 7 1 7 3 7 2 9 8 10 3 1 3 4 8 6 10 3 3 9 10 8
 4 7 2 3 10 4 2 10 5 8 9 5 6 1 4 7 2 1 7 4 3 1 7 2 6 6 5 8 7 6 7 10 4 8 5 6 3 6
 5 8 5 5 4 1 8 9 7 9 9 5 4 2 5 10 3 1 7 9 10 3 7 7 5 10 6 1 5 9 8 2 8 3 8 3 3 7
 2 1 7 2 6 10 5 10 1 10 2 8 8 2 2 6 10 8 8 7 8 4 7 6 7 4 10 5 9 2 3 10 4 10 1 9
 9 6 1 10 7 4 9 6 7 2 2 6 10 9 5 9 2 1 4 1 5 5 5 5 8 7 4 2 8 6 10 7 3 2 8 9 6 8
 5 2 9 6 10 8 6 4 9 9 4 2 9 10 7 5 4 4 4 9 7 1 5 9 9 9 10 8 8 7 5 4 1 4 ]

Process 1 sending sum 655 back to main...
Total sum of array is 1272
```

4.)Write a program to illustrate basic MPI communication routines.

Code:

```
#include <mpi.h>
#include <stdio.h>

int main(int argc, char **argv)
{
   // Initialize the MPI environment
   MPI_Init(NULL, NULL);
   // Get the number of processes
   int world_size;
   MPI_Comm_size(MPI_COMM_WORLD, &world_size);
   // COMM_WORLD is the communicator world
   // a communicator is a group of processes
   // communicating with each other and HAVE BEEN
   // init
   // Get the rank of the process
   int world_rank;
   MPI_Comm_rank(MPI_COMM_WORLD, &world_rank);
   // Get the name of the processor
   char processor_name[MPI_MAX_PROCESSOR_NAME];
   int name_len;
   MPI_Get_processor_name(processor_name, &name_len);
   printf("Hello world from process %s, rank %d out of %d processes\n\n", processor_name,
world_rank, world_size);
   if (world_rank == 0)
   {
      char *message = "Hello!";
      MPI_Send(message, 6, MPI_CHAR, 1, 0, MPI_COMM_WORLD);
   }
   else
   {
      char message[6];
      MPI_Recv(message, 6, MPI_CHAR, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
      printf("Message received!\n");
      printf("Message is : %s\n", message);
   }
   // write message send and recieve here...
   // Print off a hello world message
   // Finalize the MPI environment.
   MPI_Finalize();
   return 0;
}
```

Output:

```
kaushal@kaushal-VirtualBox:~/hpc$ touch hello_mpi.c
kaushal@kaushal-VirtualBox:~/hpc$ mpicc hello_mpi.c -o hello_mpi
kaushal@kaushal-VirtualBox:~/hpc$ mpirun -np 2 ./hello_mpi
Hello world from process kaushal-VirtualBox, rank 0 out of 2 processes

Hello world from process kaushal-VirtualBox, rank 1 out of 2 processes

Message received!
Message is : Hello!kaushal-VirtualBox
```

5.) Design a parallel program for summing up an array, matrix multiplication and show logging and tracing MPI activity.

Code:

```
#include <stdio.h>
#include "mpi.h"
#define NUM_ROWS_A 8
#define NUM_COLUMNS_A 10
#define NUM_ROWS_B 10
#define NUM_COLUMNS_B 8
#define MASTER_TO_SLAVE_TAG 1 // tag for messages sent from master to slaves
#define SLAVE_TO_MASTER_TAG 4 // tag for messages sent from slaves to master
void create_matrix();
void printArray();
int rank;
int size;
int i, j, k;
double A[NUM_ROWS_A][NUM_COLUMNS_A];
double B[NUM_ROWS_B][NUM_COLUMNS_B];
double result[NUM_ROWS_A][NUM_COLUMNS_B];
int low_bound;      // low bound of the number of rows of [A] allocated to a slave
int upper_bound;    // upper bound of the number of rows of [A] allocated to a slave
int portion;        // portion of the number of rows of [A] allocated to a slave
MPI_Status status;  // store status of a MPI_Recv
MPI_Request request; // capture request of a MPI_Send
int main(int argc, char *argv[])
{
   MPI_Init(&argc, &argv);
   MPI_Comm_rank(MPI_COMM_WORLD, &rank);
   MPI_Comm_size(MPI_COMM_WORLD, &size);
   if (rank == 0)
   { // master process
      create_matrix();
      for (i = 1; i < size; i++)
      {
         portion = (NUM_ROWS_A / (size - 1)); // portion without master
         low_bound = (i - 1) * portion;
         if (((i + 1) == size) && ((NUM_ROWS_A % (size - 1)) != 0))
         {                        // if rows of [A] cannot be equally divided among slaves
            upper_bound = NUM_ROWS_A; // last slave gets all the remaining rows
         }
         else
         {
            upper_bound = low_bound + portion; // rows of [A] are equally divisible among slaves
         }
         MPI_Send(&low_bound, 1, MPI_INT, i, MASTER_TO_SLAVE_TAG,

               MPI_COMM_WORLD);

         MPI_Send(&upper_bound, 1, MPI_INT, i, MASTER_TO_SLAVE_TAG + 1,
```

```
            MPI_COMM_WORLD);

      MPI_Send(&A[low_bound][0], (upper_bound - low_bound) * NUM_COLUMNS_A,

            MPI_DOUBLE, i, MASTER_TO_SLAVE_TAG + 2, MPI_COMM_WORLD);
   }
}
// broadcast [B] to all the slaves
MPI_Bcast(&B, NUM_ROWS_B * NUM_COLUMNS_B, MPI_DOUBLE, 0, MPI_COMM_WORLD);
/* Slave process*/
if (rank > 0)
{
   MPI_Recv(&low_bound, 1, MPI_INT, 0, MASTER_TO_SLAVE_TAG, MPI_COMM_WORLD,

         &status);

   MPI_Recv(&upper_bound, 1, MPI_INT, 0, MASTER_TO_SLAVE_TAG + 1,

         MPI_COMM_WORLD, &status);

   MPI_Recv(&A[low_bound][0], (upper_bound - low_bound) * NUM_COLUMNS_A,

         MPI_DOUBLE, 0, MASTER_TO_SLAVE_TAG + 2, MPI_COMM_WORLD, &status);

   printf("Process %d calculating for rows %d to %d of Matrix A\n", rank,

        low_bound, upper_bound);

   for (i = low_bound; i < upper_bound; i++)
   {
      for (j = 0; j < NUM_COLUMNS_B; j++)
      {
         for (k = 0; k < NUM_ROWS_B; k++)
         {
            result[i][j] += (A[i][k] * B[k][j]);
         }
      }
   }
   MPI_Send(&low_bound, 1, MPI_INT, 0, SLAVE_TO_MASTER_TAG, MPI_COMM_WORLD);
   MPI_Send(&upper_bound, 1, MPI_INT, 0, SLAVE_TO_MASTER_TAG + 1,

         MPI_COMM_WORLD);

   MPI_Send(&result[low_bound][0], (upper_bound - low_bound) * NUM_COLUMNS_B,

         MPI_DOUBLE, 0, SLAVE_TO_MASTER_TAG + 2, MPI_COMM_WORLD);
}
/* master gathers processed work*/
if (rank == 0)
{
```

```
      for (i = 1; i < size; i++)
      {
         MPI_Recv(&low_bound, 1, MPI_INT, i, SLAVE_TO_MASTER_TAG, MPI_COMM_WORLD,

               &status);

         MPI_Recv(&upper_bound, 1, MPI_INT, i, SLAVE_TO_MASTER_TAG + 1,

               MPI_COMM_WORLD, &status);

         MPI_Recv(&result[low_bound][0], (upper_bound - low_bound) * NUM_COLUMNS_B,
MPI_DOUBLE, i, SLAVE_TO_MASTER_TAG + 2, MPI_COMM_WORLD, &status);
      }
      printArray();
   }
   MPI_Finalize();
   return 0;
}
void create_matrix()
{
   for (i = 0; i < NUM_ROWS_A; i++)
   {
      for (j = 0; j < NUM_COLUMNS_A; j++)
      {
         A[i][j] = i + j;
      }
   }
   for (i = 0; i < NUM_ROWS_B; i++)
   {
      for (j = 0; j < NUM_COLUMNS_B; j++)
      {
         B[i][j] = i * j;
      }
   }
}
void printArray()
{
   printf("The matrix A is: \n");
   for (i = 0; i < NUM_ROWS_A; i++)
   {
      printf("\n");
      for (j = 0; j < NUM_COLUMNS_A; j++)
         printf("%8.2f ", A[i][j]);
   }
   printf("\n\n\n");
   printf("The matrix B is: \n");
   for (i = 0; i < NUM_ROWS_B; i++)
   {
      printf("\n");
      for (j = 0; j < NUM_COLUMNS_B; j++)
         printf("%8.2f ", B[i][j]);
```

```
    }
    printf("\n\n\n");
    printf("The result matrix is: \n");
    for (i = 0; i < NUM_ROWS_A; i++)
    {
        printf("\n");
        for (j = 0; j < NUM_COLUMNS_B; j++)
            printf("%8.2f ", result[i][j]);
    }
    printf("\n\n");
}
```

Output

```
kaushal@kaushal-VirtualBox:~/hpc$ touch matrix_mul.c
kaushal@kaushal-VirtualBox:~/hpc$ mpicc matrix_mul.c -o matrix_mul
kaushal@kaushal-VirtualBox:~/hpc$ mpirun -np 2 ./matrix_mul
Process 1 calculating for rows 0 to 8 of Matrix A
The matrix A is:

    0.00     1.00     2.00     3.00     4.00     5.00     6.00     7.00     8.0
0     9.00
    1.00     2.00     3.00     4.00     5.00     6.00     7.00     8.00     9.0
0    10.00
    2.00     3.00     4.00     5.00     6.00     7.00     8.00     9.00    10.0
0    11.00
    3.00     4.00     5.00     6.00     7.00     8.00     9.00    10.00    11.0
0    12.00
    4.00     5.00     6.00     7.00     8.00     9.00    10.00    11.00    12.0
0    13.00
    5.00     6.00     7.00     8.00     9.00    10.00    11.00    12.00    13.0
0    14.00
    6.00     7.00     8.00     9.00    10.00    11.00    12.00    13.00    14.0
0    15.00
    7.00     8.00     9.00    10.00    11.00    12.00    13.00    14.00    15.0
0    16.00
```

```
The matrix B is:

    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     1.00     2.00     3.00     4.00     5.00     6.00     7.00
    0.00     2.00     4.00     6.00     8.00    10.00    12.00    14.00
    0.00     3.00     6.00     9.00    12.00    15.00    18.00    21.00
    0.00     4.00     8.00    12.00    16.00    20.00    24.00    28.00
    0.00     5.00    10.00    15.00    20.00    25.00    30.00    35.00
    0.00     6.00    12.00    18.00    24.00    30.00    36.00    42.00
    0.00     7.00    14.00    21.00    28.00    35.00    42.00    49.00
    0.00     8.00    16.00    24.00    32.00    40.00    48.00    56.00
    0.00     9.00    18.00    27.00    36.00    45.00    54.00    63.00


The result matrix is:

    0.00   285.00   570.00   855.00  1140.00  1425.00  1710.00  1995.00
    0.00   330.00   660.00   990.00  1320.00  1650.00  1980.00  2310.00
    0.00   375.00   750.00  1125.00  1500.00  1875.00  2250.00  2625.00
    0.00   420.00   840.00  1260.00  1680.00  2100.00  2520.00  2940.00
    0.00   465.00   930.00  1395.00  1860.00  2325.00  2790.00  3255.00
    0.00   510.00  1020.00  1530.00  2040.00  2550.00  3060.00  3570.00
    0.00   555.00  1110.00  1665.00  2220.00  2775.00  3330.00  3885.00
    0.00   600.00  1200.00  1800.00  2400.00  3000.00  3600.00  4200.00
```

6.) Write a C program with openMP to implement loop work sharing.

Code:

```
#include <omp.h>
#include <stdio.h>
void reset_freq(int *freq, int THREADS)
{
   for (int i = 0; i < THREADS; i++)
      freq[i] = 0;
}

int main()
{
   int n, THREADS, i;
   printf("Enter the number of iterations :");
   scanf("%d", &n);
   printf("Enter the number of threads (max 8): ");
   scanf("%d", &THREADS);
   int freq[THREADS];
   reset_freq(freq, THREADS);
   // simple parallel for with unequal iterations
   #pragma omp parallel for num_threads(THREADS)
   for (i = 0; i < n; i++)
   {
      // printf("Thread num %d executing iter %d\n", omp_get_thread_num(), i);
      freq[omp_get_thread_num()]++;
   }
   #pragma omp barrier
   printf("\nIn default scheduling, we have the following thread distribution :- \n");
   for (int i = 0; i < THREADS; i++)
   {
      printf("Thread %d : %d iters\n", i, freq[i]);
   }
   // using static scheduling
   int CHUNK;
   printf("\nUsing static scheduling...\n");
   printf("Enter the chunk size :");
   scanf("%d", &CHUNK);
   // using a static, round robin schedule for the loop iterations
   reset_freq(freq, THREADS);
   // useful when the workload is ~ same across each thread, not when otherwise
   #pragma omp parallel for num_threads(THREADS) schedule(static, CHUNK)
   for (i = 0; i < n; i++)
   {
      // printf("Thread num %d executing iter %d\n", omp_get_thread_num(), i);
      freq[omp_get_thread_num()]++;
   }
   #pragma omp barrier
   printf("\nIn static scheduling, we have the following thread distribution :- \n");
   for (int i = 0; i < THREADS; i++)
```

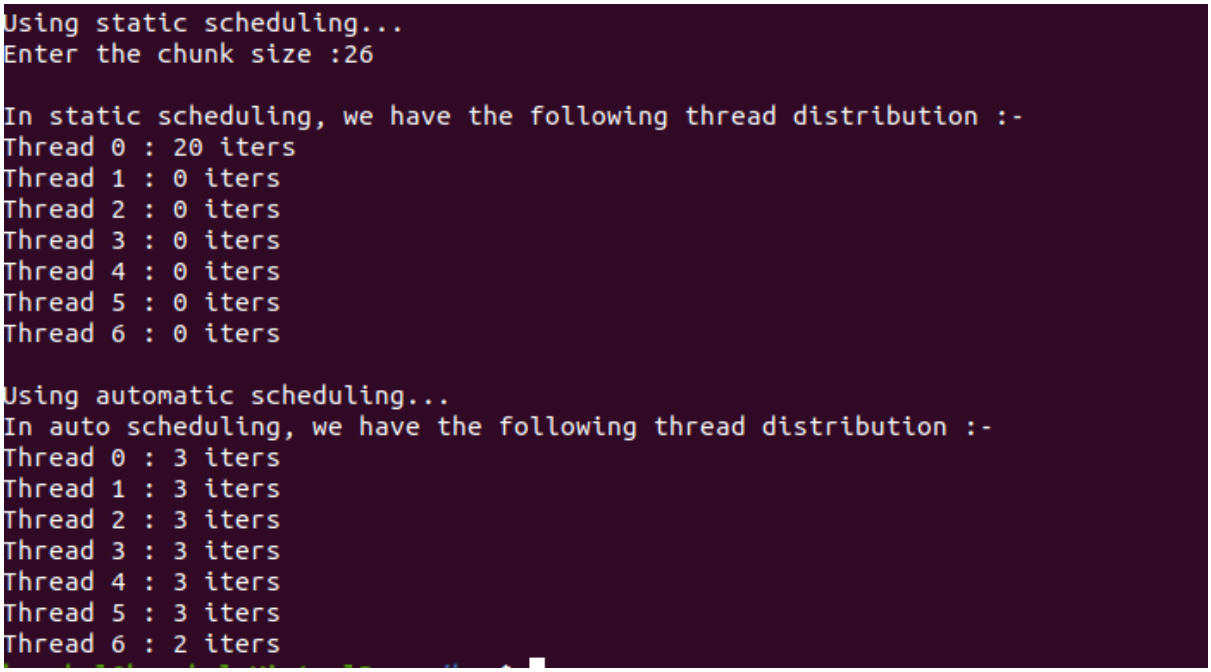
```
    {
        printf("Thread %d : %d iters\n", i, freq[i]);
    }
    // auto scheduling depending on the compiler
    printf("\nUsing automatic scheduling...\n");
    reset_freq(freq, THREADS);
    #pragma omp parallel for num_threads(THREADS) schedule(auto)
    for (i = 0; i < n; i++)
    {
        // printf("Thread num %d executing iter %d\n", omp_get_thread_num(), i);
        freq[omp_get_thread_num()]++;
    }
    #pragma omp barrier
    printf("In auto scheduling, we have the following thread distribution :- \n");
    for (int i = 0; i < THREADS; i++)
    {
        printf("Thread %d : %d iters\n", i, freq[i]);
    }
    return 0;
}
```

Output

```
In default scheduling, we have the following thread distribution :-
Thread 0 : 3 iters
Thread 1 : 3 iters
Thread 2 : 3 iters
Thread 3 : 3 iters
Thread 4 : 3 iters
Thread 5 : 3 iters
Thread 6 : 2 iters

Using static scheduling...
Enter the chunk size :26

In static scheduling, we have the following thread distribution :-
Thread 0 : 20 iters
Thread 1 : 0 iters
Thread 2 : 0 iters
Thread 3 : 0 iters
Thread 4 : 0 iters
Thread 5 : 0 iters
Thread 6 : 0 iters
```


Using static scheduling...
Enter the chunk size :26
In static scheduling, we have the following thread distribution :-
Thread 0 : 20 iters
Thread 1 : 0 iters
Thread 2 : 0 iters
Thread 3 : 0 iters
Thread 4 : 0 iters
Thread 5 : 0 iters
Thread 6 : 0 iters
Using automatic scheduling...
In auto scheduling, we have the following thread distribution :-
Thread 0 : 3 iters
Thread 1 : 3 iters
Thread 2 : 3 iters
Thread 3 : 3 iters
Thread 4 : 3 iters
Thread 5 : 3 iters
Thread 6 : 2 iters

7.) Write a C program with openMP to implement sections work

Code:

```
#include <omp.h>
#include <stdio.h>
void reset_freq(int *freq, int THREADS)
{
   for (int i = 0; i < THREADS; i++)
      freq[i] = 0;
}

int main()
{
   int n, THREADS, i;
   printf("Enter the number of iterations :");
   scanf("%d", &n);
   printf("Enter the number of threads (max 8): ");
   scanf("%d", &THREADS);
   int freq[THREADS];
   reset_freq(freq, THREADS);
   // simple parallel for with unequal iterations
   #pragma omp parallel for num_threads(THREADS)
   for (i = 0; i < n; i++)
   {
      // printf("Thread num %d executing iter %d\n", omp_get_thread_num(), i);
      freq[omp_get_thread_num()]++;
   }
   #pragma omp barrier
   printf("\nIn default scheduling, we have the following thread distribution :- \n");
   for (int i = 0; i < THREADS; i++)
   {
      printf("Thread %d : %d iters\n", i, freq[i]);
   }
   // using static scheduling
   int CHUNK;
   printf("\nUsing static scheduling...\n");
   printf("Enter the chunk size :");
   scanf("%d", &CHUNK);
   // using a static, round robin schedule for the loop iterations
   reset_freq(freq, THREADS);
   // useful when the workload is ~ same across each thread, not when otherwise
   #pragma omp parallel for num_threads(THREADS) schedule(static, CHUNK)
   for (i = 0; i < n; i++)
   {
      // printf("Thread num %d executing iter %d\n", omp_get_thread_num(), i);
      freq[omp_get_thread_num()]++;
   }
   #pragma omp barrier
   printf("\nIn static scheduling, we have the following thread distribution :- \n");
   for (int i = 0; i < THREADS; i++)
```

```
    {
        printf("Thread %d : %d iters\n", i, freq[i]);
    }
    // auto scheduling depending on the compiler
    printf("\nUsing automatic scheduling...\n");
    reset_freq(freq, THREADS);
    #pragma omp parallel for num_threads(THREADS) schedule(auto)
    for (i = 0; i < n; i++)
    {
        // printf("Thread num %d executing iter %d\n", omp_get_thread_num(), i);
        freq[omp_get_thread_num()]++;
    }
    #pragma omp barrier
    printf("In auto scheduling, we have the following thread distribution :- \n");
    for (int i = 0; i < THREADS; i++)
    {
        printf("Thread %d : %d iters\n", i, freq[i]);
    }
    return 0;
}
```

Output:

```
kaushal@kaushal-VirtualBox:~/hpc$ ./thread_sections
Work load sharing of threads...
I am thread number 0!
I am thread number 3!
Number of values computed : 300
I am thread number 2!
Number of values computed : 200
I am thread number 1!
Number of values computed : 100
Total number of threads are 4
```

8.) Write a program to illustrate process synchronization and collective data movements.

Code:

```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
int thread_count; // this global variable is shared by all threads
// compiling information -
// gcc name_of_file.c -o name_of_exe -lpthread (link p thread)
// necessary for referencing in the thread
struct arguments
{
   int size;
   int *arr1;
   int *arr2;
   int *dot;
};
// function to parallelize`
void *add_into_one(void *arguments);
// util
void print_vector(int n, int *arr)
{
   printf("[ ");
   for (int i = 0; i < n; i++)
      printf("%d ", arr[i]);
   printf("] \n");
}
// main driver function of the program
int main(int argc, char *argv[])
{
   long thread;
   // /* Use long in case of a 64-bit system */
   pthread_t *thread_handles;
   thread_count = 2; // using 2 threads only
   // get the thread handles equal to total num
   // of threads
   thread_handles = malloc(thread_count * sizeof(pthread_t));
   printf("Enter the size of the vectors : ");
   int n;
   scanf("%d", &n);
   printf("Enter the max_val of the vectors : ");
   int max_val;
   scanf("%d", &max_val);
   struct arguments *args[2]; // array of pointer to structure
   // each element is a pointer
   for (int i = 0; i < 2; i++)
   {
      // allocate for the struct
```

```
        args[i] = malloc(sizeof(struct arguments) * 1);
        // allocate for the arrays
        args[i]->size = n;
        args[i]->arr1 = malloc(sizeof(int) * n);
        args[i]->arr2 = malloc(sizeof(int) * n);
        args[i]->dot = malloc(sizeof(int) * n);
        for (int j = 0; j < n; j++)
        {
            args[i]->arr1[j] = rand() % max_val;
            args[i]->arr2[j] = rand() % max_val;
        }
    }
    printf("Vectors are : \n");
    print_vector(n, args[0]->arr1);
    print_vector(n, args[0]->arr2);
    print_vector(n, args[1]->arr1);
    print_vector(n, args[1]->arr2);
    int result[n];
    memset(result, 0, n * sizeof(int));
    // note : we need to manually startup our threads
    // for a particular function which we want to execute in
    // the thread
    for (thread = 0; thread < thread_count; thread++)
    {
        printf("Multiplying %ld and %ld with thread %ld...\n", thread + 1, thread + 2,
               thread);
        pthread_create(&thread_handles[thread], NULL, add_into_one, (void *)args[thread]);
    }
    printf("Hello from the main thread\n");
    // wait for completion
    for (thread = 0; thread < thread_count; thread++)
        pthread_join(thread_handles[thread], NULL);
    for (int i = 0; i < 2; i++)
    {
        printf("Multiplication for vector %d and %d \n", i + 1, i + 2);
        print_vector(n, args[i]->dot);
        printf("\n");
    }
    free(thread_handles);
    // now compute the summation of results
    for (int i = 0; i < n; i++)
        result[i] = args[0]->dot[i] + args[1]->dot[i];
    printf("Result is : \n");
    print_vector(n, result);
    return 0;
}
void *add_into_one(void *argument)
{
    // de reference the argument
    struct arguments *args = argument;
    // compute the dot product into the
```

```
    // array dot
    int n = args->size;
    for (int i = 0; i < n; i++)
        args->dot[i] = args->arr1[i] * args->arr2[i];
    return NULL;
}
```

Output

```
kaushal@kaushal-VirtualBox:~/hpc$ touch thread_vector.c
kaushal@kaushal-VirtualBox:~/hpc$ gcc thread_vector.c -o thread-vector -lpthrea
d
kaushal@kaushal-VirtualBox:~/hpc$ ./thread-vector
Enter the size of the vectors : 5
Enter the max_val of the vectors : 3
Vectors are :
[ 1 0 2 1 0 ]
[ 1 1 1 0 1 ]
[ 2 2 2 0 1 ]
[ 1 1 1 0 1 ]
Multiplying 1 and 2 with thread 0...
Multiplying 2 and 3 with thread 1...
Hello from the main thread
Multiplication for vector 1 and 2
[ 1 0 2 0 0 ]

Multiplication for vector 2 and 3
[ 2 2 2 0 1 ]

Result is :
[ 3 2 4 0 1 ]
```