NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA SURATHKAL

DEPARTMENT OF INFORMATION TECHNOLOGY

IT 301 Parallel Computing LAB 3 (Ritik Pansuriya - 181IT237)

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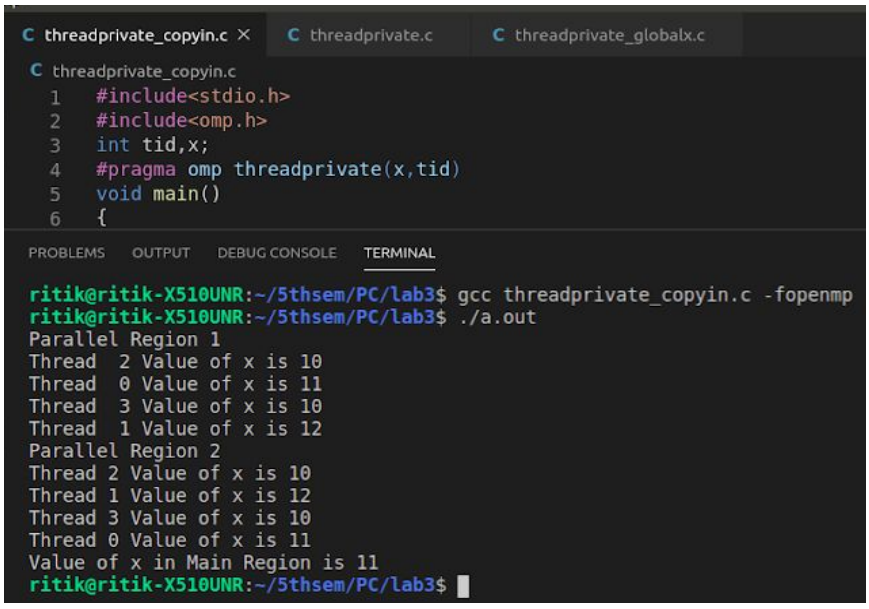
1. Program 1 - copyin clause provides a mechanism to copy the value of a threadprivate variable of the master thread to the threadprivate variable of each other member of the team that is executing the parallel region. Barrier is used to take all the thread simultaneously at one position.

Execute following code and observe the working of threadprivate directive and copyin clause:

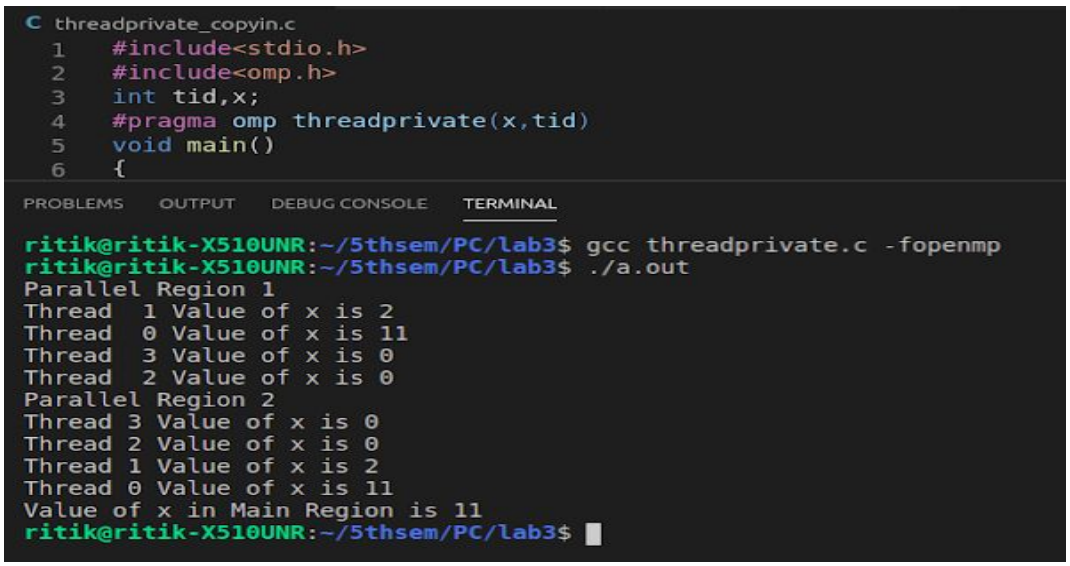
```
#include<stdio.h>

#include<omp.h>

int tid,x;

#pragma omp threadprivate(x,tid)

void main()

{

x=10;

#pragma omp parallel num_threads(4) copyin(x)

{

tid=omp_get_thread_num();

#pragma omp master

{

printf("Parallel Region 1 \n");

x=x+1;

}
```

```
#pragma omp barrier
if(tid==1)
x=x+2;
printf("Thread % d Value of x is %d\n",tid,x);
}//#pragma omp barrier
#pragma omp parallel num_threads(4)
{
#pragma omp master
{
printf("Parallel Region 2 \n");
}
#pragma omp barrier
printf("Thread %d Value of x is %d\n",tid,x);
}
printf("Value of x in Main Region is %d\n",x);
}
```



As threadprivate() assigns x=10 to the master thread, copyin(x) copies into all other threads the value assigned in the master thread. Barrier clause indicates that all thread must wait at that position for all thread at that place. Main region is changed by the master region.

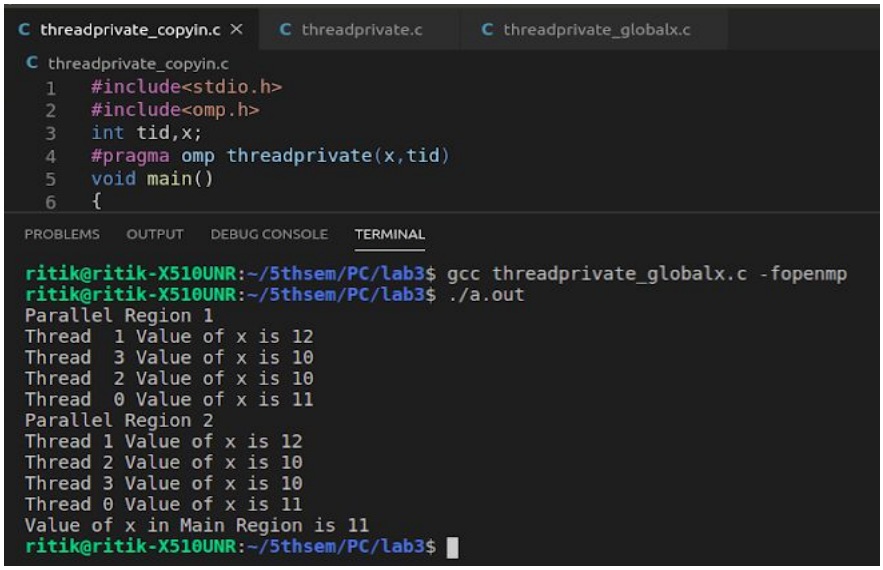
DO the following: 1. Remove the copyin clause and check the output.



As threadprivate() assigns x=10 to the master thread,as no copyin so thread is initialized to 0. Barrier clause indicates that all thread must wait at that position for all thread at that place. Main region is changed by the master region.

2. Remove the copyin clause and initialize x globally.

As x is assigned globally, all threads will copy the same value.

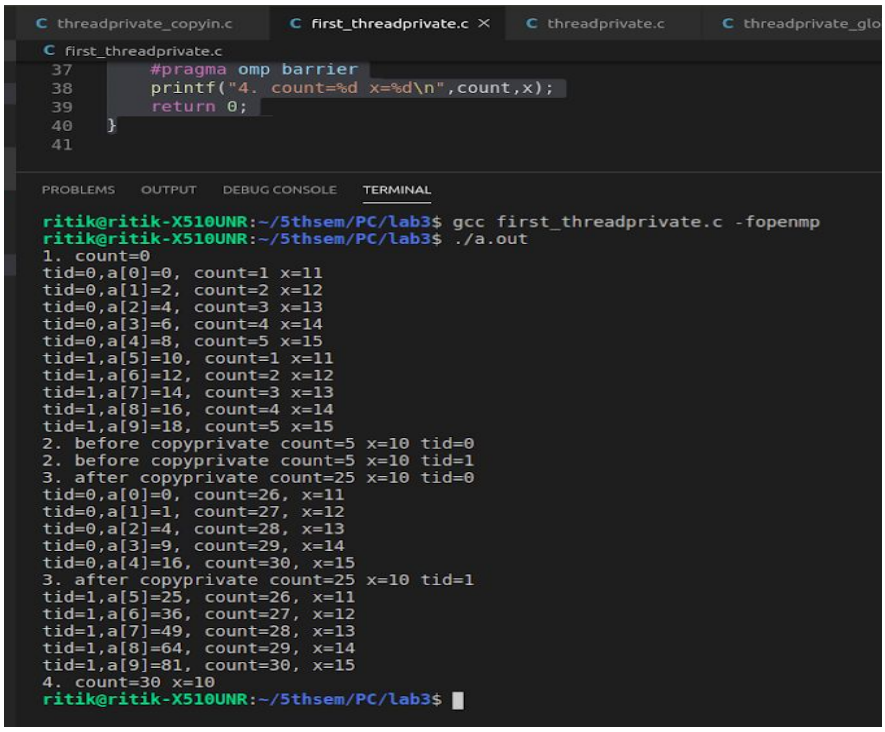


2. Program 2 - Learn the concept of firstprivate() and threadprivate()

```
#include <stdio.h>
#include <stdlib.h>
#include <omp.h>
int count=0;
#pragma omp threadprivate(count)
int main (void) {
int x=10, y=20,a[10],b[10],c[10],i;
//int count=0;
for(i=0;i<10;i++)
b[i]=c[i]=i;
printf("1. count=%d\n",count);
#pragma omp parallel num_threads(2) copyin(count)
{
#pragma omp for schedule(static,5) firstprivate(x)
for(i=0;i<10;i++)
{
int tid1=omp_get_thread_num();
a[i]=b[i]+c[i];
count++;
x++;
printf("tid=%d,a[%d]=%d, count=%d x=%d\n",tid1,i,a[i],count,x);
}
#pragma omp barrier
printf("2. before copyprivate count=%d x=%d tid=%d\n",count,x,omp_get_thread_num());
```

```
#pragma omp single copyprivate(count)
{
count=count+20;
}
printf("3. after copyprivate count=%d x=%d tid=%d\n",count,x,omp_get_thread_num());
#pragma omp for schedule(static,5) firstprivate(x)
for(i=0;i<10;i++)
{
int tid1=omp_get_thread_num();
a[i]=b[i]*c[i];
count++;
x++;
printf("tid=%d,a[%d]=%d, count=%d, x=%d\n",tid1,i,a[i],count,x);
}
}
#pragma omp barrier
printf("4. count=%d x=%d\n",count,x);
printf("\n");
return 0;
}
```

---As count is initialized globally and threadprivate(count) count is global to all the threads. Everytime firstprivate(x) is encountered x=10 is initialized in each thread for that region alone. However as count is global to the thread its value is retained whereas x's value isn't not global so it's value is not retained. Single copyprivate(count) only one time count value is added by 20.



3. Program to understand the concept of collapse()

```
#include <stdio.h>

#include <stdlib.h>

#include <omp.h>

int main (void) {

int i,j;

#pragma omp parallel

{

#pragma omp for schedule(static,3) private(i,j)

for(i=0;i<6;i++)

for(j=0;j<5;j++)

{

int tid2=omp_get_thread_num();

printf("tid=%d, i=%d j=%d\n",omp_get_thread_num(),i,j);
```

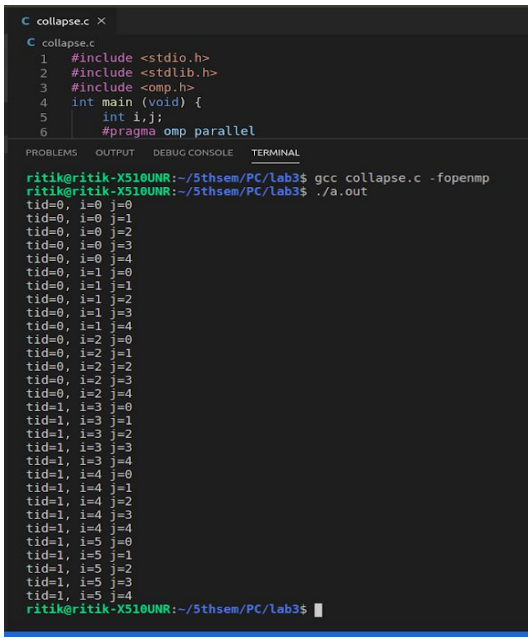
}

}

return 0;

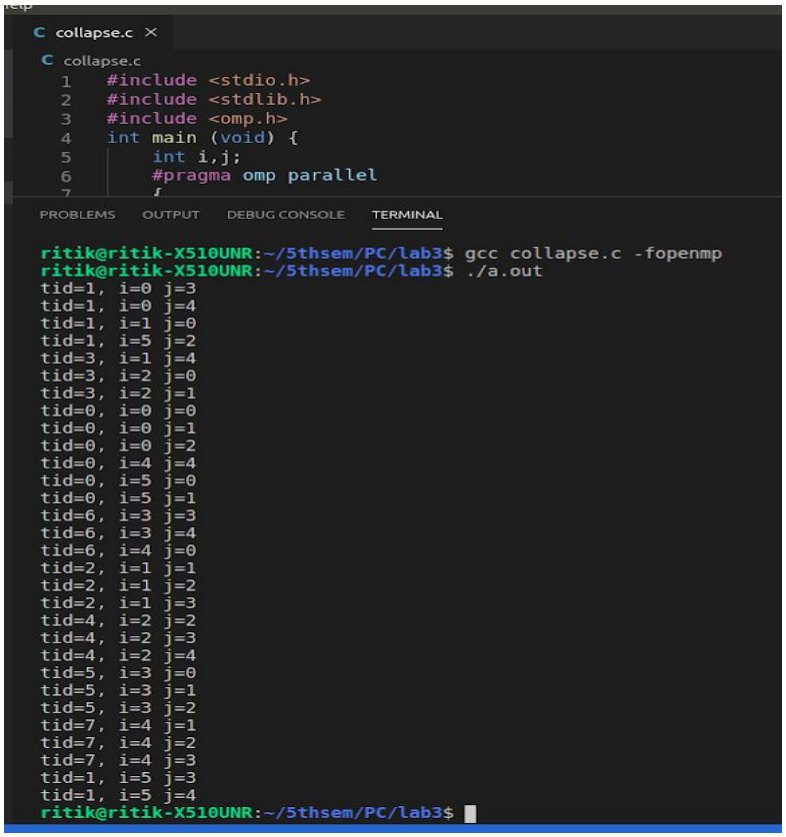
}

Consider three for loops and check the result with no collapse():



No collapse so normal order of the iteration is followed by i,j.

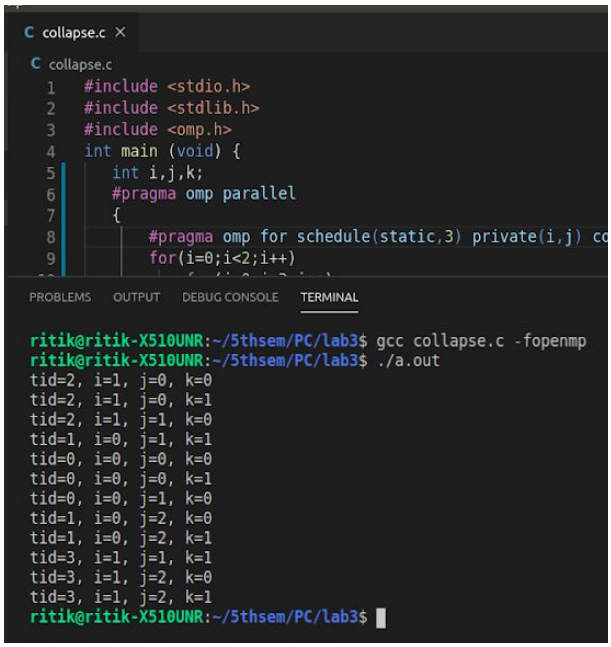
collapse(2)



As both the for loop are not interconnected the order of execution can be anything.

collapse(3).

```c
#include <stdio.h>
#include <stdlib.h>
#include <omp.h>
int main (void) {
   int i,j,k;
   #pragma omp parallel
   {
       #pragma omp for schedule(static,3) private(i,j) collapse(3)
       for(i=0;i<2;i++)
           for(j=0;j<3;j++)
           {
               for(k=0; k<2; k++){
                   int tid2=omp_get_thread_num();
          printf("tid=%d, i=%d, j=%d, k=%d\n",omp_get_thread_num(),i,j,k);
               }
           }
   }
   return 0;
}
```



Same as collapse 2 instead we have i, j, k in random fashion.

4. How to compare sequential and parallel program execution times. ?

Include following header files in the program.

```
#include <sys/time.h>

#include <stdlib.h>
```

//Declare following variables.

```
struct timeval TimeValue_Start;

struct timezone TimeZone_Start;

struct timeval TimeValue_Final;

struct timezone TimeZone_Final;

long time_start, time_end;

double time_overhead;
```

Just before starting parallel region code , note down the time(start time)

```
gettimeofday(&TimeValue_Start, &TimeZone_Start);
```

After finishing parallel region, get end time.

```
gettimeofday(&TimeValue_Final, &TimeZone_Final);
```

Calculate the overhead time as follows:

```
time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;

time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;

time_overhead = (time_end - time_start)/1000000.0;

printf("\n\n\t\t Time in Seconds (T) : %lf",time_overhead);
```

Example

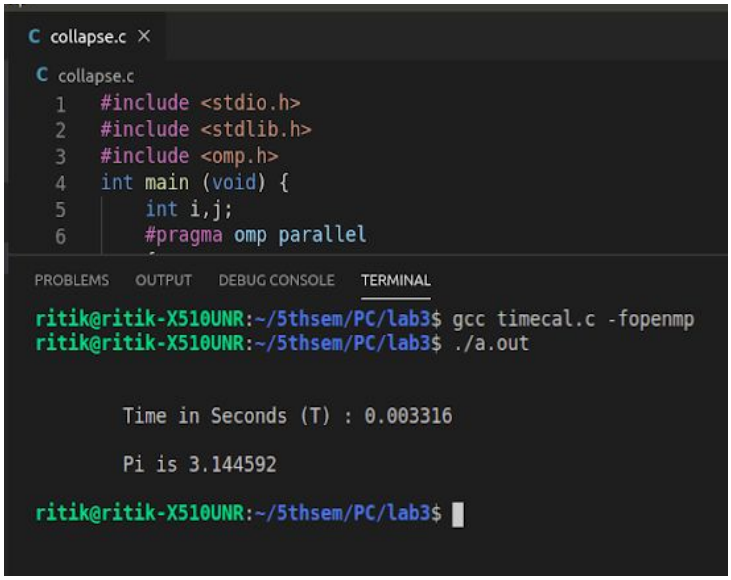
```
#include <stdio.h>

#include <sys/time.h>
```

```
#include <omp.h>
#include <stdlib.h>
int main(void){
struct timeval TimeValue_Start;
struct timezone TimeZone_Start;
struct timeval TimeValue_Final;
struct timezone TimeZone_Final;
long time_start, time_end;
double time_overhead;double pi,x;
int i,N;
pi=0.0;
N=1000;
gettimeofday(&TimeValue_Start, &TimeZone_Start);
#pragma omp parallel for private(x) reduction(+:pi)
for(i=0;i<=N;i++){
x=(double)i/N;
pi+=4/(1+x*x);
}
gettimeofday(&TimeValue_Final, &TimeZone_Final);
time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
time_overhead = (time_end - time_start)/1000000.0;
printf("\n\n\tTime in Seconds (T) : %lf\n",time_overhead);
```

pi=pi/N;

printf("\n \tPi is %f\n\n",pi);

}



3. Write a sequential program to find the smallest element in an array. Convert the same program for parallel execution. Initialise array with random numbers. Consider an array size as 10k, 50k and 100k. Analyse the result for maximum number of threads and various schedule() functions. Based on observation, perform analysis of the total execution time and explain the result by plotting the graph. [increase array size until parallel execution time is less than sequential execution.

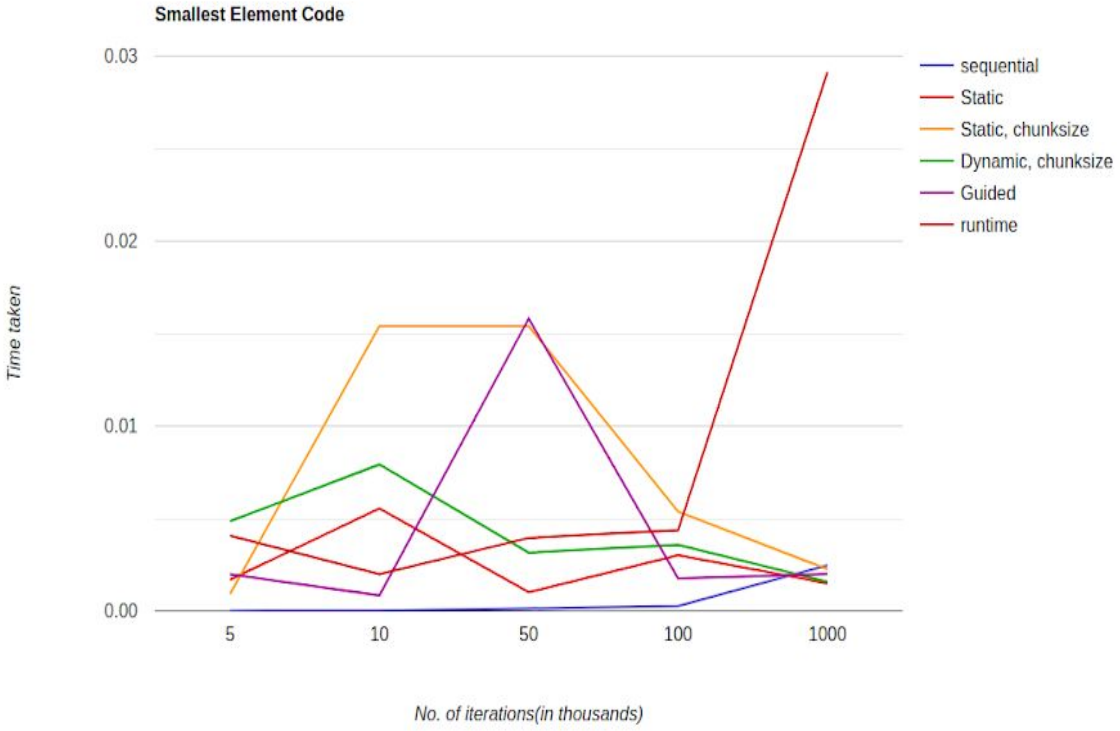
```
#include <stdio.h>

#include <sys/time.h>

#include <omp.h>

#include <stdlib.h>

int main(){

   struct timeval TimeValue_Start;

   struct timezone TimeZone_Start;

   struct timeval TimeValue_Final;

   struct timezone TimeZone_Final;

   long time_start1, time_end1;

   double time_overhead1;

   int n=100000;

         int array[n],i;

   for(int i=0; i<n; i++){

      array[i]=rand();

   }

   long time_start2, time_end2;

   double time_overhead2;

         int cur_min2=array[0];

   gettimeofday(&TimeValue_Start, &TimeZone_Start);
```

```
#pragma omp parallel for schedule(guided,8) num_threads(8)
for(i=0; i<n; i++){
   if(array[i]<cur_min2)
      #pragma omp critical
         if(array[i]<cur_min2)
            cur_min2=array[i];
}
gettimeofday(&TimeValue_Final, &TimeZone_Final);
time_start2 = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
time_end2 = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
time_overhead2 = (time_end2 - time_start2)/1000000.0;
printf("\n\n\tTime in Parallal Seconds (T) : %lf\n",time_overhead2);
        printf("The smallest number in given array is %d\n",cur_min2);
        int cur_min1=array[0];
gettimeofday(&TimeValue_Start, &TimeZone_Start);
for(int i=1; i<n; i++){
   if(cur_min1 > array[i]) cur_min1=array[i];
}
gettimeofday(&TimeValue_Final, &TimeZone_Final);
time_start1 = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
time_end1 = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
time_overhead1 = (time_end1 - time_start1)/1000000.0;
printf("\n\n\tTime in Sequential Seconds (T) : %lf\n",time_overhead1);
        printf("The smallest number in given array is %d\n",cur_min1);
```

```
    return 0;

}
```

Schedule()	Total Execution time for number of iterations 5K	Total execution for number of iterations 10K	Total execution for number of iterations 50K	Total execution for number of iterations 100K	Total execution for number of iterations 1000K
Sequential execution	0.000013	0.000029	0.000141	0.00028	0.002478
Static	0.001694	0.005555	0.001018	0.003020	0.001505
Static, chunksize	0.000928	0.015404	0.015404	0.005376	0.002266
Dynamic, chunksize	0.004858	0.007924	0.003158	0.003586	0.001580
Guided	0.001997	0.000845	0.015811	0.001770	0.002008
runtime	0.004074	0.002	0.003956	0.004378	0.029139

Sequential execution gave better runtimes for lower iterations due to the fact that for the threading process the time taken to thread the process is also added along with the execution time. However when the iterations are very large then parallel code has lesser runtime. Also increasing the number of threads reduces the runtime but upto some extent(20 thread gives lowest runtime for me). Value of N=1000000 leads that sequential has more execution time then parallel execution.


Smallest Element Code
0.03
0.02
0.01
0.00
Time taken
5
10
50
100
1000
No. of iterations(in thousands)
sequential
Static
Static, chunksize
Dynamic, chunksize
Guided
runtime