Report for HPC LAB

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Programming Environment: OpenMP
Problem: Vector Addition
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Hardware Configuration:

CPU NAME	:	Intel core i7 – 9700 @ 3.00 Ghz
Number of Sockets:	:	1
Cores per Socket	:	8
Threads per core	:	1
L1 Cache size	:	32KB
L2 Cache size	:	256KB
L3 Cache size(Shared):		12MB
RAM	:	16 GB

Serial Code:

```
#include <stdio.h>
#include<time.h>
#include<stdlib.h>

#define n 100000
#define m 100000

int main()
{
        double a[n],b[n], c[n];
        float startTime, endTime,execTime;
        int i,k;
        int omp_rank;
        float rtime;



        startTime = omp_get_wtime();
        for(i=0;i<n;i++)
        {

                a[i] = i * 10.236 ;        // Use Random function and assign a[i]
                b[i] = i * 152.123;        // Use Random function and assign b[i]
                for(int j=0;j<m;j++)
                        c[i] = a[i] + b[i];
                //printf("The value of a[%d] = %lf and b[%d] = %lf and result c[%d] = %lf done by worker Thread ID = %d\n", i, a[i], i, b[i], i, c[i], omp_rank);
        }
        endTime = omp_get_wtime();

        execTime = endTime - startTime;
        rtime[k]=execTime;
        printf("\n rtime=%f\n",rtime);
        return(0);
}
```

Parallel Code:

```
#include <stdio.h>
#include<time.h>
#include <omp.h>
#include<stdlib.h>

#define n 100000
#define m 100000

int main()
{
        double a[n],b[n], c[n];
        float startTime, endTime,execTime;
        int i,k;
        int omp_rank;
        float rtime[20];
        int thread[]={1,2,4,6,8,10,12,16,20,32,64,128,150};
        int thread_arr_size=13;
        for(k=0;k<thread_arr_size;k++)
        {
                omp_set_num_threads(thread[k]);

                startTime = omp_get_wtime();

                #pragma omp parallel private (i) shared (a,b,c)
                {
                        #pragma omp for
                        for(i=0;i<n;i++)
                        {

                                omp_rank = omp_get_thread_num();
                                a[i] = i * 10.236 ;     // Use Random function and assign a[i]
                                b[i] = i * 152.123;     // Use Random function and assign b[i]
                                for(int j=0;j<m;j++)
                                        c[i] = a[i] + b[i];
        //                      printf("The value of a[%d] = %lf and b[%d] = %lf and result c[%d] = %lf done by worker Thread ID = %d\n", i, a[i], i, b[i], i, c[i], omp_rank);
                        }

                }
                endTime = omp_get_wtime();
                execTime = endTime - startTime;
                rtime[k]=execTime;
        }
        for (k=0;k<thread_arr_size;k++)
                printf("\nThread=%d\t rtime=%f\n",thread[k],rtime[k]);
        return(0);
}
```

Compilation and Execution:
For enabling OpenMP environment use -fopenmp flag while compiling using gcc.

```
gcc -fopenmp vectoradd.c -o vectoradd
```

For execution use

```
./vectoradd
```

Observations:

Number of Threads	Execution Time	Speed-up	Parallelization Fraction
1	17.427979	1	
2	8.925049	1.95	97.6
4	4.468066	3.90	99.2
6	2.980898	5.85	99.5
8	**2.214966**	7.87	**99.8**
10	3.092041	5.64	91.4
12	3.017822	5.78	90.2
16	2.981445	5.85	88.4
20	2.974854	5.86	87.3
32	2.910645	5.99	86.0
64	2.892334	6.03	84.7
128	2.931152	5.95	83.8
150	3.003662	5.80	83.3

Speed up can be found using the following formula,

$$S(n)=T(1)/T(n)$$

where, S(n) = Speedup for thread count ‘n’
T(1) = Execution Time for Thread count ‘1’ (serial code)
T(n) = Execution Time for Thread count ‘n’ (serial code)

Parallelization Fraction can be found using the following formula,

$$S(n)=1/((1 - p) + p/n)$$

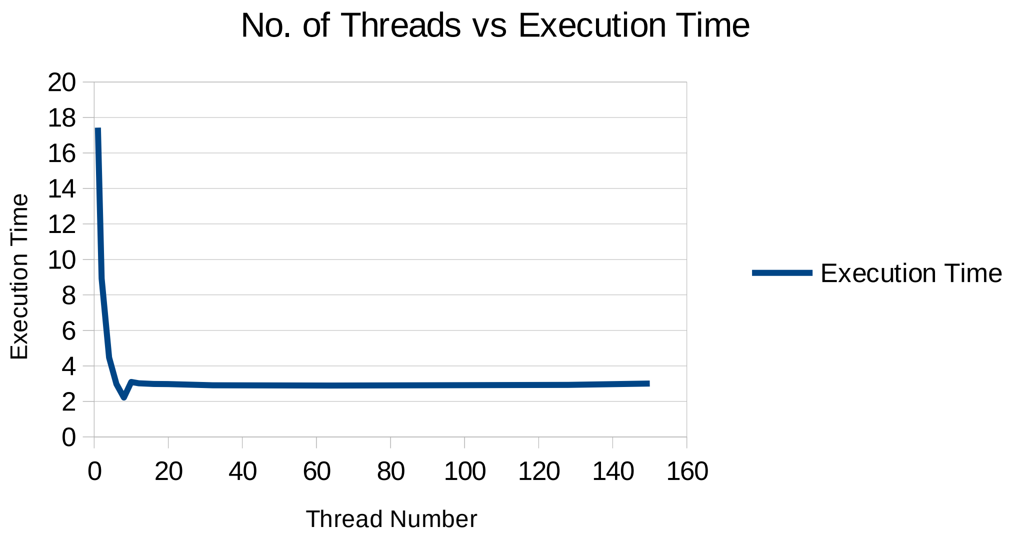
where, S(n) = Speedup for thread count ‘n’
n = Number of threads
p = Parallelization fraction

Assumption:

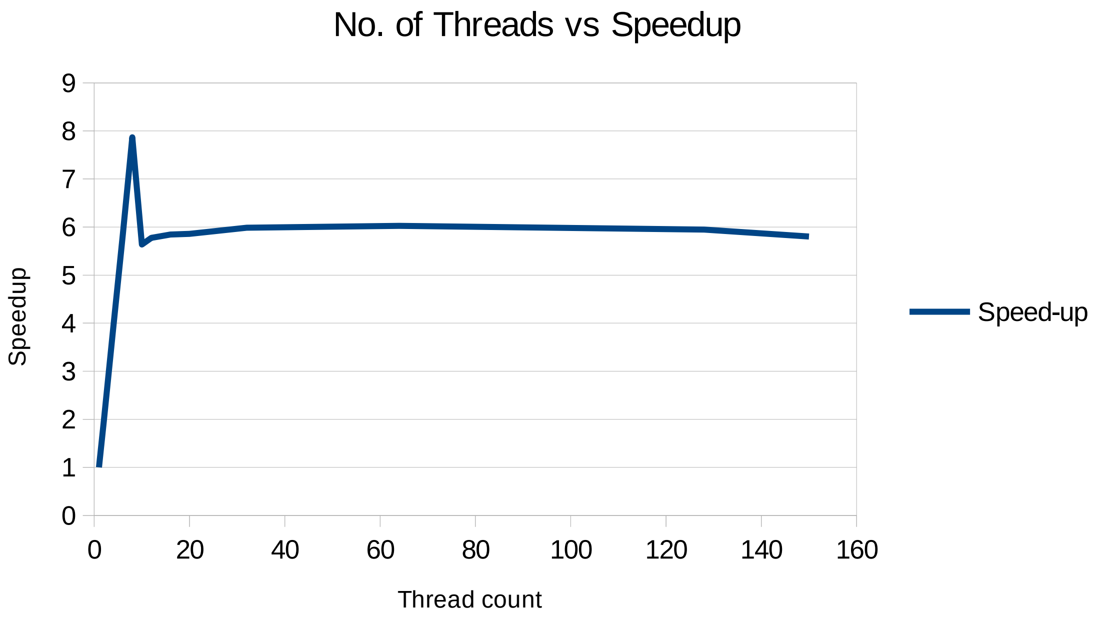
Following extra for loop is added to increase the number of operations in the parallel region to visualize the effect of multi-threading in vector addition.

```
for(int j=0;j<m;j++)
        c[i] = a[i] + b[i];
```

Number of Threads vs Execution Time:



Number of Threads vs Speedup:



Inference: (Note: Exection time, graph and inference will be based on hardware configuration**)**

- At thread count 8 maximum speedup is observed as the maximux number of parallel thread supported by the hardware is 8.
- If thread count is more than 8 then the execution time increases slightly and tapers out after 16 threads.