Report for HPC LAB

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Programming Environment: MPI
Problem: Vector Addition
Date: 22nd October 2021

Hardware Configuration:

CPU NAME : Intel core i5 – 8250U @ 1.60 GHz
Number of Sockets : 1
Cores per Socket : 4
Threads per core : 2
L1 Cache size : 32KB (Per Core)
L2 Cache size : 256KB (Per Core)
L3 Cache size : 6MB (Shared)
RAM : 8 GB

Serial Code:

```
#include <stdio.h>
#include <time.h>
#include <stdlib.h>
#include <omp.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 = execTime;
	printf("\n rtime=%f\n", rtime);
	return (0);
}
```

Parallel Code :

```
#include "mpi.h"
#include <stdio.h>
#include <stdlib.h>
#define array_size 1000
#define MASTER 0
#define FROM_MASTER 1
#define FROM_WORKER 2
int main(int argc, char *argv[])
{
	int numtasks, taskid, numworkers, source, dest, mtype, segment, aveseg, extra,
		offset, i, j, k, rc;
	double starttime, endtime;
	long double a[array_size], b[array_size], c[array_size];
	MPI_Status status;
	//starttime = MPI_Wtime();
	MPI_Init(&argc, &argv);
	starttime = MPI_Wtime();
	MPI_Comm_rank(MPI_COMM_WORLD, &taskid);
	MPI_Comm_size(MPI_COMM_WORLD, &numtasks);
	if (numtasks < 2)
	{
		printf("Need atleast two MPI tasks. Quiting...\n");
		MPI_Abort(MPI_COMM_WORLD, rc);
		exit(1);
	}
	numworkers = numtasks - 1;
	//master task:
	if (taskid == MASTER)
	{
		for (i = 0; i < array_size; i++)
			a[i] = i;
		for (j = 0; j < array_size; j++)
			b[j] = j;
		aveseg = array_size / numworkers;
		extra = array_size % numworkers;
		offset = 0;
		mtype = FROM_MASTER;
		for (dest = 1; dest <= numworkers; dest++)
		{
			segment = (dest <= extra) ? aveseg + 1 : aveseg;
			MPI_Send(&offset, 1, MPI_INT, dest, mtype, MPI_COMM_WORLD);
			MPI_Send(&segment, 1, MPI_INT, dest, mtype,
MPI_COMM_WORLD);
			MPI_Send(&a[offset], segment, MPI_LONG_DOUBLE, dest, mtype,
					MPI_COMM_WORLD);
			MPI_Send(&b[offset], segment, MPI_LONG_DOUBLE, dest, mtype,
					MPI_COMM_WORLD);
			offset = offset + segment;
		}
```

```
		//receive from worker:
		mtype = FROM_WORKER;
		for (i = 1; i <= numworkers; i++)
		{
			source = i;
			MPI_Recv(&offset, 1, MPI_INT, source, mtype, MPI_COMM_WORLD,
&status);
			MPI_Recv(&segment, 1, MPI_INT, source, mtype,
MPI_COMM_WORLD,
					&status);
			MPI_Recv(&c[offset], segment, MPI_LONG_DOUBLE, source, mtype,
					MPI_COMM_WORLD, &status);
		}
		printf("\nResultant Vector:\n");
		for (i = 0; i < array_size; i++)
			printf("%6.2Lf \n", c[i]);
		endtime = MPI_Wtime();
		printf("That took %f seconds\n", endtime - starttime);
		printf("\nDone.\n");
	}
	//Worker task:
	if (taskid > MASTER)
	{
		mtype = FROM_MASTER;
		MPI_Recv(&offset, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD,
&status);
		MPI_Recv(&segment, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD,
				&status);
		MPI_Recv(&a, segment, MPI_LONG_DOUBLE, MASTER, mtype,
				MPI_COMM_WORLD, &status);
		MPI_Recv(&b, segment, MPI_LONG_DOUBLE, MASTER, mtype,
				MPI_COMM_WORLD, &status);
		//mat addition
		for (i = 0; i < segment; i++)
			c[i] = a[i] + b[i];
		mtype = FROM_WORKER;
		MPI_Send(&offset, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD);
		MPI_Send(&segment, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD);
		MPI_Send(&c, segment, MPI_LONG_DOUBLE, MASTER, mtype,
				MPI_COMM_WORLD);
	}
	MPI_Finalize();
}
```

Output :

```
mpiuser@c01: ~/mirror/Lab-1
File  Edit  View  Search  Terminal  Help
mpiuser@c01:~/mirror/Lab-1$ mpicc parallel.cpp
mpiuser@c01:~/mirror/Lab-1$ for i in {2,4,6,8,12,16,20,32,64,128}; do mpirun -n $i -f machinefile ./a.out; done
For Number of tasks = 2   Time = 0.029474 seconds
For Number of tasks = 4   Time = 0.060982 seconds
For Number of tasks = 6   Time = 0.097324 seconds
For Number of tasks = 8   Time = 0.126716 seconds
For Number of tasks = 12   Time = 0.322481 seconds
For Number of tasks = 16   Time = 0.266797 seconds
For Number of tasks = 20   Time = 0.312358 seconds
For Number of tasks = 32   Time = 1.079776 seconds
For Number of tasks = 64   Time = 12.728408 seconds
For Number of tasks = 128   Time = 62.935448 seconds
mpiuser@c01:~/mirror/Lab-1$
```

Compilation and Execution:

Compiling using mpicc parallel.cpp

For execution use

for i in {2,4,6,8,12,16,20,32,64,128}; do mpirun -n $i -f machinefile ./a.out

Observations:

Number of Threads	**Execution Time**	**Speed-up**	**Parallelization Fraction**
1	0.012	1	
2	0.029	0.41	-2.878
4	0.06	0.2	-5.3333
6	0.09	0.13	-8.0308
8	0.12	0.1	-10.2857
12	0.32	0.04	-26.1818
16	0.26	0.05	-20.2667
20	0.31	0.04	-25.2632
32	1.07	0.01	-102.1935
64	12.72	0.0009	-1127.7319
128	62.93	0.0002	-5038.3622

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)

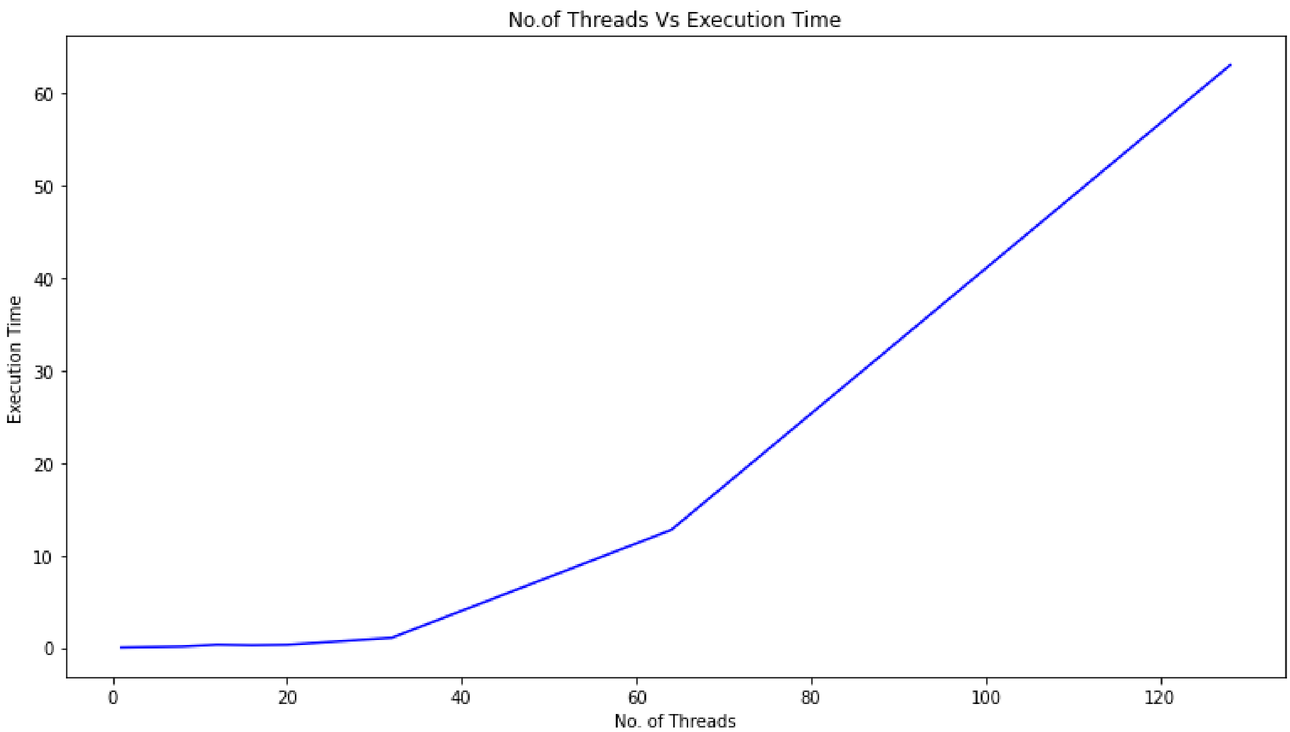
Parallelization Fraction can be found using the following formula, **S(n)=1/((1 - p) + p/n)**

where, S(n) = Speedup for thread count 'n'

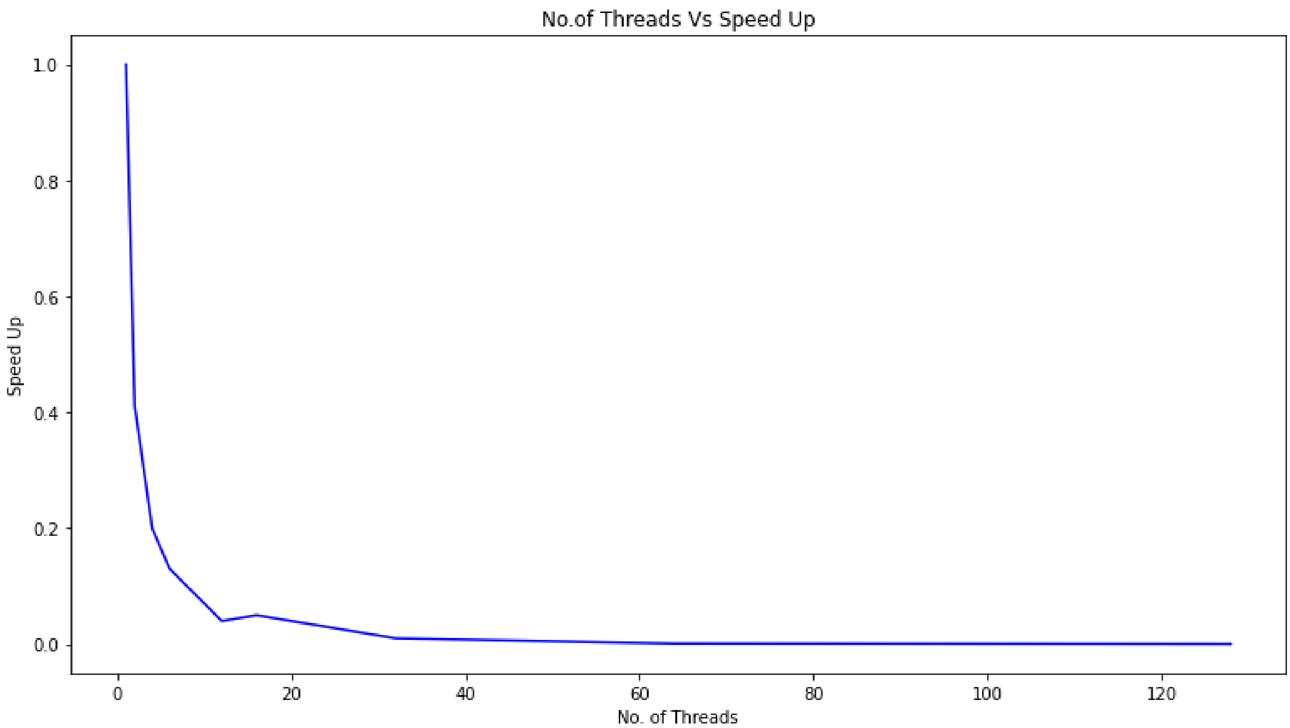
n = Number of threads

p = Parallelization fraction

Number of Threads vs Execution Time:



Number of Threads vs Speed Up:



Inference:

- Execution time increasing with increase in number of threads

Since the problem is of smaller complexity the overheads of parallelization seem to have more effects here.