



**Sinhgad Institutes**

**Sinhgad Technical Education Society's**

**SINHGAD ACADEMY OF ENGINEERING,**

**PUNE-411048**

**DEPARTMENT OF COMPUTER ENGINEERING**

**Laboratory manual (Instructor's Manual)**

**Course 410255:  
Laboratory Practice V**

Prepared by:

- Mr. G.S.Nikam

## **Vision**

उत्तमपुरुषान् उत्तमाभियंत्रन् निर्मातुं कटीबद्धः वयम् !

“We are committed to produce not only good engineers but good human beings, also.”

## **Mission**

“Holistic development of students and teachers is what we believe in and work for. We strive to achieve this by imbining a unique value system, transparent work culture, excellent academic and physical environment conducive to learning, creativity and technology transfer. Our mandate is to generate, preserve and share knowledge for developing a vibrant society.”

# **Department of Computer Engineering**

## **Vision**

“To build the Department as a Centre of Excellence for students in Computer Engineering.”

## **Mission**

“We believe in developing value based system for student and staff by providing healthy and transparent work culture to cultivate new ideas in the field of engineering and technology which will contribute to build a vibrant Society.”

### **Programme Outcomes (POs)**

**PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

**PO2. Problem analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

**PO3. Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

**PO4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

**PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

**PO6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

**PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO8. Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

**PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

### **Programme Specific Outcomes (PSOs)**

Computer Engineering graduate will be able to,

**PSO1: Project Development:** Successfully complete hardware and/or software related system or application projects, using the phases of project development life cycle to meet the requirements of service and product industries; government projects; and automate other engineering stream projects.

**PSO2: Domain Expertise:** Demonstrate effective application of knowledge gained from different computer domains like, data structures, data bases, operating systems, computer networks, security, parallel programming, in project development, research and higher education.

**PSO3: Career Development:** Achieve successful Career and Entrepreneurship- The ability to employ modern computer languages, environments, and platforms in creating innovative career paths to be an entrepreneur, and a zest for higher studies.

**Savitribai Phule Pune University**  
**Fourth Year of Computer Engineering (2019 Course)**  
**410255: Laboratory Practice V**

<b>Teaching Scheme:</b> <b>Practical: 2 Hours/Week</b>	<b>Credit</b> <b>01</b>	<b>Examination Scheme</b> <b>Term Work: 50 Marks</b> <b>Practical: 50 Marks</b>
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**Companion Course:** High Performance Computing(410250), Deep Learning(410251)

**Course Objectives:**

- To understand and implement searching and sorting algorithms.
- To learn the fundamentals of GPU Computing in the CUDA environment.
- To illustrate the concepts of Artificial Intelligence/Machine Learning(AI/ML).
- To understand Hardware acceleration.
- To implement different deep learning models.

**Course Outcomes:**

- CO1: Analyze and measure** performance of sequential and parallel algorithms.  
**CO2: Design and Implement** solutions for multicore/Distributed/parallel environment.  
**CO3: Identify and apply** the suitable algorithms to solve AI/ML problems.  
**CO4: Apply** the technique of Deep Neural network for implementing Linear regression and classification.  
**CO5: Apply** the technique of Convolution (CNN) for implementing Deep Learning models.  
**CO6: Design and develop** Recurrent Neural Network (RNN) for prediction.

**Guidelines for Instructor's Manual**

Laboratory Practice V is for practical hands on for core courses High Performance Computing and Data Learning. The instructor's manual is to be developed as a hands-on resource and as ready reference. The instructor's manual need to include prologue (about University/program/ institute/ department/foreword/ preface etc), University syllabus, conduction and Assessment guidelines, topics under consideration-concept, objectives, outcomes, set of typical applications/assignments/ guidelines, references among others.

**Guidelines for Student's Laboratory Journal**

The laboratory assignments are to be submitted by student in the form of journal. Journal may

consists of prologue, Certificate, table of contents, and handwritten write-up of each assignment (Title, Objectives, Problem Statement, Outcomes, software and Hardware requirements, Date of Completion, Assessment grade/marks and assessor's sign, Theory- Concept in brief, Algorithm/Database design, test cases, conclusion/analysis). Program codes with sample output of all performed assignments are to be submitted as softcopy.

### **Guidelines for Laboratory /Term Work Assessment**

Continuous assessment of laboratory work is to be done based on overall performance and lab assignments performance of student. Each lab assignment assessment will assign grade/marks based on parameters with appropriate weightage. Suggested parameters for overall assessment as well as each lab assignment assessment include- timely completion, performance, innovation, efficient codes, punctuality and neatness reserving weightage for successful mini-project completion and related documentation.

### **Guidelines for Practical Examination**

- Both internal and external examiners should jointly frame suitable problem statements for practical examination based on the term work completed.
- During practical assessment, the expert evaluator should give the maximum weightage to the satisfactory implementation of the problem statement.
- The supplementary and relevant questions may be asked at the time of evaluation to test the student's for advanced learning, understanding of the fundamentals, effective and efficient implementation.
- Encouraging efforts, transparent evaluation and fair approach of the evaluator will not create any uncertainty or doubt in the minds of the students. So adhering to these principles will consummate our team efforts to the promising boost to the student's academics.

### **Guidelines for Laboratory Conduction**

- List of recommended programming assignments and sample mini-projects is provided for reference.
- Referring these, Course Teacher or Lab Instructor may frame the assignments/mini-project by understanding the prerequisites, technological aspects, utility and recent trends related to the respective courses.
- Preferably there should be multiple sets of assignments/mini-project and distribute among batches of students.
- Real world problems/application based assignments/mini-projects create interest among learners serving as foundation for future research or startup of business projects.
- Mini-project can be completed in group of 2 to 3 students.

- Software Engineering approach with proper documentation is to be strictly followed.
- Use of open source software is to be encouraged.
- Instructor may also set one assignment or mini-project that is suitable to respective course beyond the scope of syllabus.

Operating System recommended :- 64-bit Open source Linux or its derivative

Programming Languages: Object Oriented Languages

C++/JAVA/PYTHON/R

Programming tools recommended: Front End: Java/Perl/PHP/Python/Ruby/.net, Backend :

MongoDB/MYSQL/Oracle, Database Connectivity : ODBC/JDBC

### **Suggested List of Laboratory Experiments/Assignments**

#### **410250 : High Performance Computing**

Any 4 Assignments and 1 Mini Project are Mandatory

##### **Group 1**

1.	Design and implement Parallel Breadth First Search and Depth First Search based on existing algorithms using OpenMP. Use a Tree or an undirected graph for BFS and DFS .
2.	Write a program to implement Parallel Bubble Sort and Merge sort using OpenMP. Use existing algorithms and measure the performance of sequential and parallel algorithms.
3.	Implement Min, Max, Sum and Average operations using Parallel Reduction.
4.	Write a CUDA Program for : <ol style="list-style-type: none"> <li>1. Addition of two large vectors</li> <li>2. Matrix Multiplication using CUDA C</li> </ol>
5.	Implement HPC application for AI/ML domain.

##### **Group 2**

6.	Mini Project: Evaluate performance enhancement of parallel Quicksort Algorithm using MPI
7.	Mini Project: Implement Huffman Encoding on GPU
8.	Mini Project: Implement Parallelization of Database Query optimization
9.	Mini Project: Implement Non-Serial Polyadic Dynamic Programming with GPU Parallelization

#### **410251 : Deep Learning**

Any 3 Assignments and 1 Mini Project are Mandatory

##### **Group 1**

1.	<b>Linear regression by using Deep Neural network:</b> Implement Boston housing price prediction problem by Linear regression using Deep Neural network. Use Boston House price prediction dataset.
2.	<b>Classification using Deep neural network</b> (Any One from the following) <ol style="list-style-type: none"> <li>1. Multiclass classification using Deep Neural Networks: Example: Use the OCR letter recognition dataset <a href="https://archive.ics.uci.edu/ml/datasets/letter+recognition">https://archive.ics.uci.edu/ml/datasets/letter+recognition</a></li> <li>2. Binary classification using Deep Neural Networks Example: Classify movie reviews into "positive" reviews and "negative" reviews, just based on the text content of the reviews. Use IMDB dataset</li> </ol>
3.	<b>Convolutional neural network (CNN)</b> (Any One from the following) <ul style="list-style-type: none"> <li>• Use any dataset of plant disease and design a plant disease detection system using CNN.</li> <li>• Use MNIST Fashion Dataset and create a classifier to classify fashion clothing into categories.</li> </ul>
4.	<b>Recurrent neural network (RNN)</b> Use the Google stock prices dataset and design a time series analysis and prediction system using RNN.
<b>Group 2</b>	
5.	<b>Mini Project:</b> Human Face Recognition
6.	<b>Mini Project:</b> Gender and Age Detection: predict if a person is a male or female and also their age
7.	<b>Mini Project:</b> Colorizing Old B&W Images: color old black and white images to colorful images

**@The CO-PO Mapping Matrix**

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	-	1	1	-	2	1	-	-	-	-	-
CO2	1	2	1	-	-	1	-	-	-	-	-	1
CO3	-	1	1	1	1	1	-	-	-	-	-	-
CO4	3	3	3	-	3	-	-	-	-	-	-	-
CO5	3	3	3	3	3	-	-	-	-	-	-	-
CO6	3	3	3	3	3	-	-	-	-	-	-	-
CO7	3	3	3	3	3		-	-	-	-	-	-



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# Experiment 1

<b>Title</b>	Design and implement Parallel Breadth First Search and Depth First Search
<b>Problem statement</b>	Design and implement Parallel Breadth First Search and Depth First Search based on existing algorithms using OpenMP. Use a Tree or an undirected graph for BFS and DFS .
<b>Prerequisite</b>	64-bit Open source Linux or its derivative
<b>CO mapped</b>	1
<b>Programming Tools</b>	Java/Perl/PHP/Python/Ruby/.net, MongoDB/MYSQL/Oracle

## Theory & Procedure:

**Title:** Design & implementation of Parallel (OpenMP) Searching algorithms for Binary search for Sorted Array and Depth-First Search (tree or an undirected graph) or Breadth-First Search (tree or an undirected graph) or Best-First Search that (traversal of graph to reach a target in the shortest possible path).

**Objectives:** To offload parallel computations to the graphics card, when it is appropriate to do so, and to give some idea of how to think about code running in the massively parallel environment presented by today's graphics cards.

**Outcome:** Students should understand the basic of OpenMP Programming Module using existing Searching techniques.

**Prerequisites:** Data Structure and Files, Design and Analysis of Algorithm, OpenMP Tutorials.

**Hardware Specification:** x86\_64 bit, 2 – 2/4 GB DDR RAM, 80 - 500 GB SATA HD.

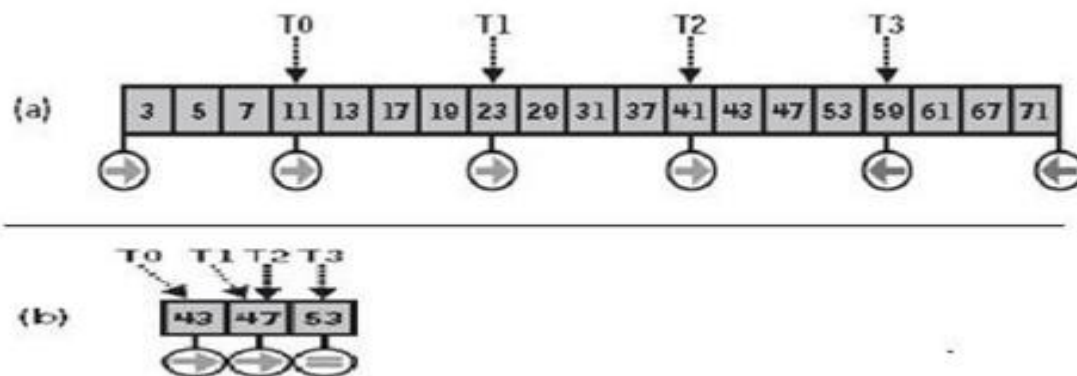
**Software Specification:** Ubuntu 14.04, G Edit, GCC Compiler.

## Introduction:

An Application Program Interface (**API**) that may be used to explicitly direct multithreaded, shared memory parallelism. An Open Multi-Processing (**OpenMP**) consists of a set of compiler *#pragmas* that control how the program works. The **pragmas** are designed so that even if the compiler does not support them, the program will still yield correct behavior, but without any parallelism. Searching identifies N well-spaced points within the search array bounds and compares the key of the corresponding records to the search key. Each thread does one of the N comparisons.

There are three possible outcomes from these comparisons. The first is that the item of interest is found and the search is complete; the second is that the item key examined is less than the search key; the third is that the item key examined is greater than the search key. If no search key match is found, a new, smaller search array is defined by the two consecutive index points whose record keys were found to be less than the search key and greater than the search key.

The N-ary search is then performed on this refined search array. As with the serial version of binary search, the process is repeated until a match is found or the number of items in the search array is zero.



Given the sorted array of prime numbers in Figure (a), let's say we want to determine whether the value 53 is in the array and where it can be found. If there are four threads (T0 to T3), each computes an index into the array and compares the key value found there to the search key. Threads T0, T1, and T2 all find that the key value at the examined position is less than the search key value. Thus, an item with the matching key value must lie somewhere to the right of each of these thread's current search positions (indicated by the circled arrows). Thread T3 determines that the examined key value is greater than the search key, and the matching key can be found to the left of this thread's search position (left-pointing circled arrow). Notice the circled arrows at each end of the array. These are attached to "phantom" elements just outside the array bounds. The results of the individual key tests define the subarray that is to become the new search array. Where we find two consecutive test results with opposite outcomes, the corresponding indexes will be just outside of the lower and upper bounds of the new search array. Figure (a) shows that the test results from threads T2 (less than search key) and T3 (greater than search key) are opposite. The new search array is the array elements between the elements tested by these two threads. Figure (b) shows this subarray and the index positions that are tested by each thread. The figure shows that during this second test of element key values, thread T3 has found the element that matches the search key. Consider the case, where find a composite value, like 52, in a list of prime numbers. The individual key results by the four threads shown in Figure (a) would be the same. The subarray shown in Figure (b) would have the same results, except that the

test by T3 would find that the key value in the assigned position was greater than the search key (and the equals sign would be a left-pointing arrow). The next round of key comparisons by threads would be from a sub array with no elements, bounded by the array slots holding the key values of 47 and 53. When threads are confronted with the search of an empty search space, then the key is not to be found. This is obviously more complex than a simple binary search. The algorithm must coordinate the choices of index positions that each thread needs to test, keep and store the results of each test such that multiple threads can examine those results, and compute the new search array bounds for the next round of key tests. From this quick description, it's clear that it needs some globally accessible data and, more importantly, it needs a barrier between the completion of the key tests and the examination of the results of those tests.

- Applications:**
1. Information retrieval in the required format is the central activity in all computer applications.
  2. Searching methods are designed to take advantage of the file organization and optimize the search for a particular record or to establish its absence.

**Conclusion:** We have tested both the Searching algorithms for different number elements with respective to time. As the number of elements increased time required for OpenMP is reduced.

## Experiment 2

<b>Title</b>	Write a program to implement Parallel Bubble Sort and Merge sort using OpenMP
<b>Problem statement</b>	Write a program to implement Parallel Bubble Sort and Merge sort using OpenMP. Use existing algorithms and measure the performance of sequential and parallel algorithms.
<b>Prerequisite</b>	64-bit Open source Linux or its derivative
<b>CO mapped</b>	2
<b>Programming Tools</b>	Java/Perl/PHP/Python/Ruby/.net, MongoDB/MYSQL/Oracle

**Objectives:** To offload parallel computations to the graphics card, when it is appropriate to do so, and to give some idea of how to think about code running in the massively parallel environment presented by today's graphics cards.

**Outcome:** Students should understand the basic of OpenMP Programming Module using existing Sorting techniques.

**Prerequisites:** Data Structure and Files, Design and Analysis of Algorithm, OpenMP Tutorials.

**Hardware Specification:** x86\_64 bit, 2 – 2/4 GB DDR RAM, 80 - 500 GB SATA HD. **Software**

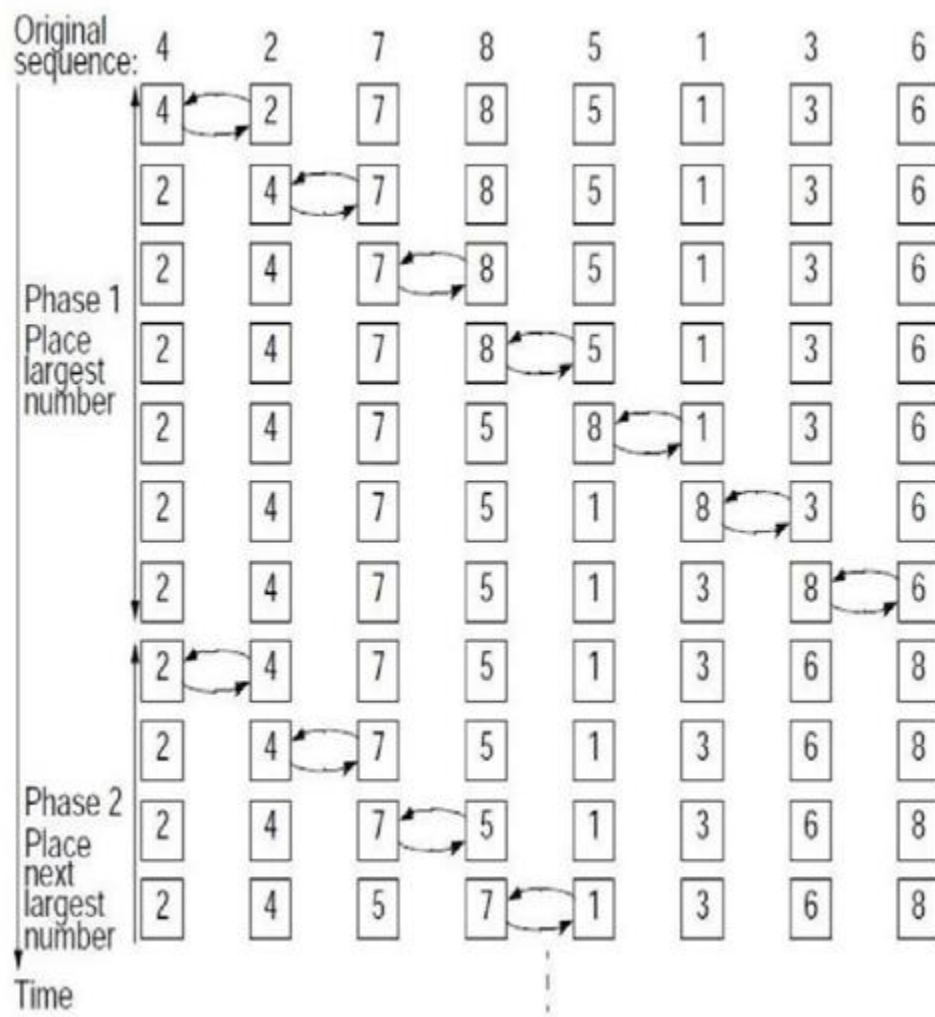
**Specification:** Ubuntu 14.04, G Edit, GCC Compiler.

### Introduction:

An Application Program Interface (**API**) that may be used to explicitly direct multithreaded, shared memory parallelism. An Open Multi-Processing (**OpenMP**) consists of a set of compiler *#pragmas* that control how the program works. The **pragmas** are designed so that even if the compiler does not support them, the program will still yield correct behavior, but without any parallelism. Sorting is the process of putting data in order; either numerically or alphabetically. It is necessary to arrange the elements in an array in numerical or lexicographical order, sorting numerical values in descending order or ascending order and alphabetical value like addressee key. Many existing sorting algorithms were observed in terms of the efficiency of the algorithmic complexity. All sorting algorithms are appropriate for specific kinds of problems. Some sorting algorithms work on less number of elements, some are used for huge number of data, some are used if the list has repeated values, and some are suitable for floating point numbers. Sorting is used in many important applications and there have been a plenty of performance analysis. There are several sorting algorithms available to sort the elements of an array. Some of the sorting algorithms are,

### A. Bubble Sort:

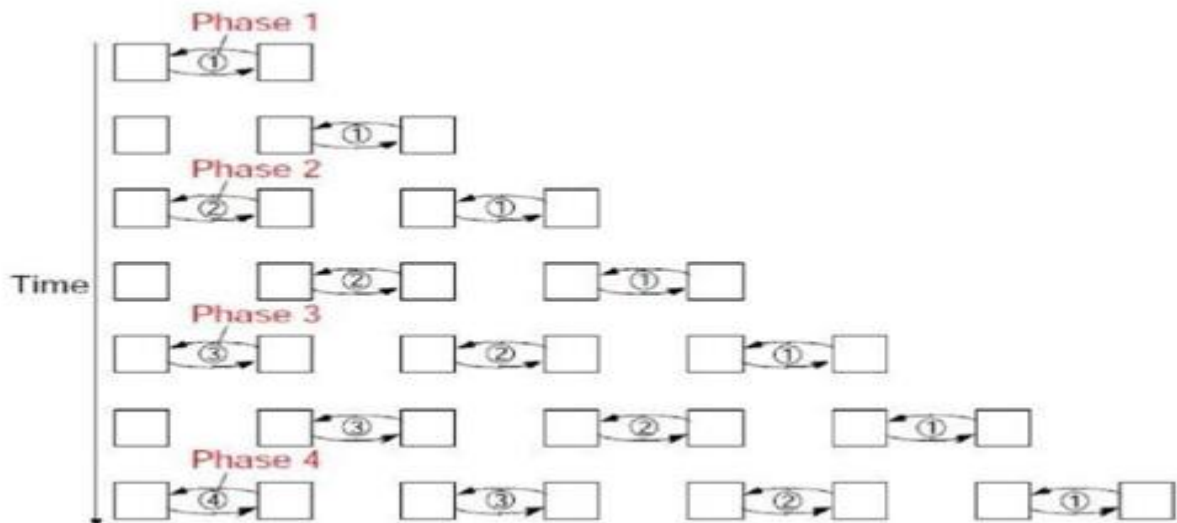
In bubble sort, the largest number is first moved to the very end of the list by a series of compare-and-exchange operations, starting at the opposite end. The procedure repeats, stopping just before the previously positioned largest number, to get the next-largest number. In this way, the larger numbers move (like a bubble) toward the end of the list.



```
for (i = N - 1; i > 0; i--)  
for (j = 0; j < i; j++) { k = j + 1;  
if (a[j] > a[k]) { temp = a[j]; a[j] = a[k];  
a[k] = temp;  
}}
```

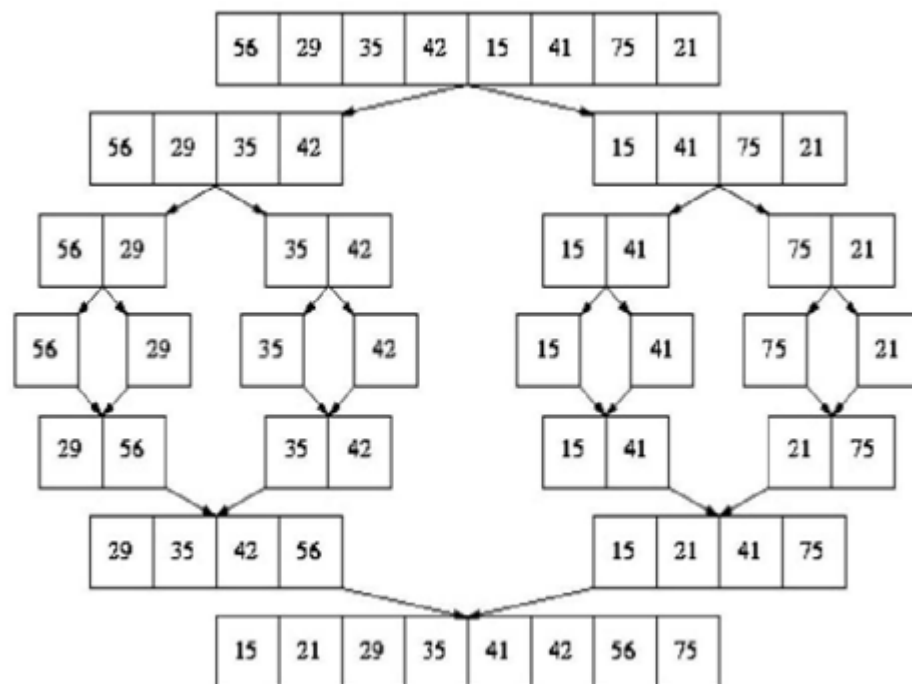
### A. Parallel Bubble Sort

A possible idea is to run multiple iterations in a pipeline fashion, i.e., start the bubbling action of the next iteration before the preceding iteration has finished in such a way that it does not overtake it.



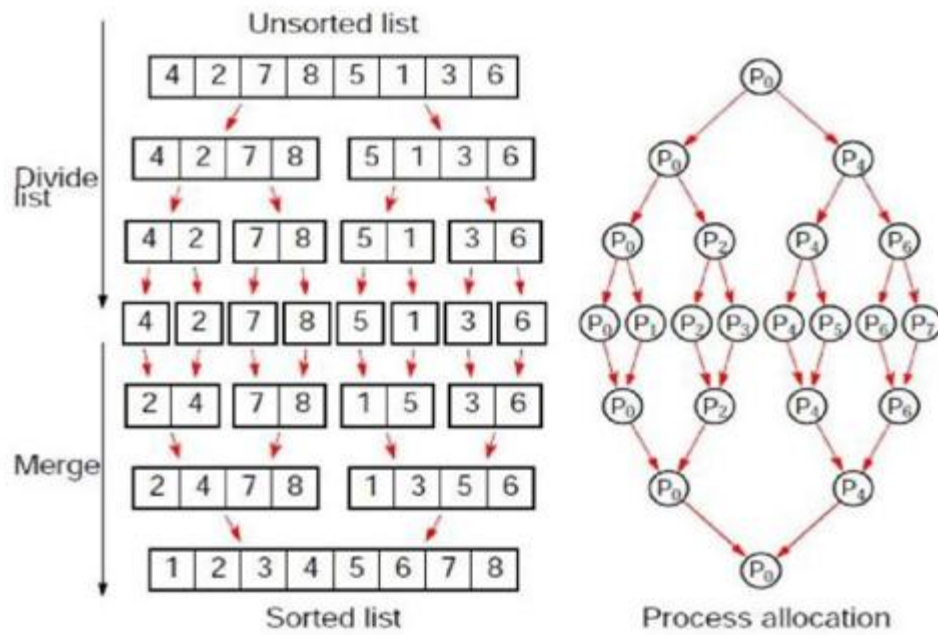
## B.Merge Sort

Merge Sort is a classical sorting algorithm using a divide-and-conquer approach. The initial unsorted list is first divided in half, each half sub list is then applied the same division method until individual elements are obtained. Pairs of adjacent elements / sub lists are then merged into sorted sub lists until the one fully merged and sorted list is obtained.



## Parallel Merge Sort

The idea is to take advantage of the tree structure of the algorithm to assign work to processes. If communication time ignore, computations still only occur when merging the sub lists. But now, in the worst case, it takes  $2s - 1$  steps to merge all sub lists (two by two) of size  $s$  in a merging step.



### Applications:

1. Bubble sort is used in programming TV remote to sort channels on the basis of longer viewing time.
2. Databases use an external merge sort to sort set of data that are too large to be loaded entirely into memory.

**Conclusion:** We have tested both the Sorting algorithms for different number elements with respective to time. As the number of elements increased time required for OpenMP is reduced.



## Experiment 3

<b>Title</b>	Implement Min, Max, Sum and Average operations using Parallel Reduction.
<b>Problem statement</b>	<p>Implement Parallel Reduction using Min, Max, Sum and Average operations.</p> <p>b) Write a CUDA program that given an N-element vector, find-</p> <ul style="list-style-type: none"><li>• The maximum element in the vector</li><li>• The minimum element in the vector</li><li>• The arithmetic mean of the vector</li><li>• The standard deviation of the values in the vector</li></ul> <p>Test for input N and generate a randomized vector V of length N (N should be large). The program should generate output as the two computed maximum values as well as the time taken to find each value.</p>
<b>Prerequisite</b>	64 bit Open source Linux or its derivative, Programming Languages: C/C++,CUDA Tutorials
<b>CO mapped</b>	3
<b>Programming Tools</b>	Ubuntu 14.04, GPU Driver 352.68, CUDA Toolkit 8.0

**Objective:** To study and implementation of directive based parallel programming model. To study and implement the operations on vector, generate o/p as two computed max values as well as time taken to find each value

**Outcome:** Students will understand the implementation of sequential program augmented with compiler directives to specify parallelism. Students will understand the implementation of operations on vector, generate o/p as two computed max with respect to time.

**Pre-requisites:** 64-bit Open source Linux or its derivative, Programming Languages: C/C++,CUDA Tutorials.

**Hardware Specification:** x86\_64 bit, 2 – 2/4 GB DDR RAM, 80 - 500 GB SATA HD, 1GB NVIDIA TITAN X Graphics Card.

**Software Specification:** Ubuntu 14.04, GPU Driver 352.68, CUDA Toolkit 8.0, CUDNN Library v5.0

**Theory:**

**Open MP:**

OpenMP is a set of C/C++ pragmas (or FORTRAN equivalents) which provide the programmer a high-level front-end interface which get translated as calls to threads (or other similar entities). The key phrase here is "higher-level"; the goal is to better enable the programmer to "think parallel," alleviating him/her of the burden and distraction of dealing with setting up and coordinating threads. For example, the OpenMP directive.

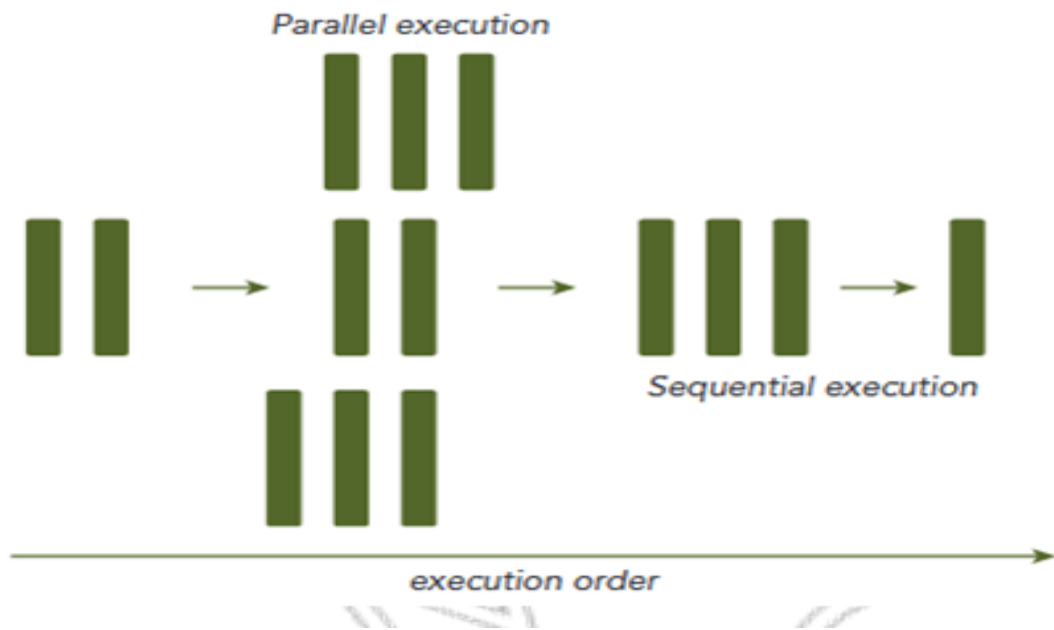
## Parallel Programming:

There are two fundamental types of parallelism in applications:

- Task parallelism
- Data parallelism

Task parallelism arises when there are many tasks or functions that can be operated independently and largely in parallel. Task parallelism focuses on distributing functions across multiple cores.

Data parallelism arises when there are many data items that can be operated on at the same time. Data parallelism focuses on distributing the data across multiple cores.



## CUDA:

CUDA programming is especially well-suited to address problems that can be expressed as data-parallel computations. Any applications that process large data sets can use a data-parallel model to speed up the computations. Data-parallel processing maps data elements to parallel threads. The first step in designing a data parallel program is to partition data across threads, with each thread working on a portion of the data.

## CUDA Architecture:

A heterogeneous application consists of two parts:

- Host code
- Device code

Host code runs on CPUs and device code runs on GPUs. An application executing on a heterogeneous platform is typically initialized by the CPU. The CPU code is responsible for managing the environment, code, and data for the device before loading compute-intensive tasks on the device. With computational intensive applications, program sections often exhibit a rich amount of data parallelism. GPUs are used to accelerate the execution of this portion of data parallelism. When a hardware component that is physically separate from the CPU is used to accelerate computationally intensive sections of an application, it is referred to as a hardware accelerator. GPUs are arguably the most common example of a hardware accelerator. GPUs must operate in conjunction with a CPU-based host through a PCI-Express bus, as shown in Figure.

NVIDIA's CUDA nvcc compiler separates the device code from the host code during the compilation process. The device code is written using CUDA C extended with keywords for labeling data-parallel

functions, called kernels . The device code is further compiled by Nvcc. During the link stage, CUDA runtime libraries are added for kernel procedure calls and explicit GPU device manipulation. Further kernel function, named hello From GPU, to print the string of“Hello World from GPU!” as follows:

```
__global__ void hello From GPU(void)
{
printf(“Hello World from GPU!\n”);
}
```

The qualifier \_\_global\_ tells the compiler that the function will be called from the CPU and executed on the GPU. Launch the kernel function with the following code:

```
Hello From GPU <<<1,10>>>();
```

Triple angle brackets mark a call from the host thread to the code on the device side. A kernel is executed by an array of threads and all threads run the same code. The parameters within the triple angle brackets are the execution configuration, which specifies how many threads will execute the kernel. In this example, you will run 10 GPU threads.

A typical processing flow of a CUDA program follows this pattern:

- 1.Copy data from CPU memory to GPU memory.
- 2.Invoke kernels to operate on the data stored in GPU memory.
- 3.Copy data back from GPU memory to CPU memory.

**Conclusion:** We have implemented parallel reduction using Min, Max, Sum and Average Operations. We have implemented CUDA program for calculating Min, Max, Arithmetic mean and Standard deviation Operations on N-element vector.

## Experiment 4

<b>Title</b>	Design & implementation of Parallel (CUDA) algorithm to Add two large Vector
<b>Problem statement</b>	Design & implementation of Parallel (CUDA) algorithm to Add two large Vector, Multiply Vector and Matrix and Multiply two $N \times N$ arrays using $n^2$ .
<b>Prerequisite</b>	Strassen's Matrix Multiplication Algorithm and CUDA Tutorials
<b>CO mapped</b>	4
<b>Programming Tools</b>	Ubuntu 14.04, GPU Driver 352.68, CUDA Toolkit 8.0, CUDNNLibrary v5.0

**Title:** Design & implementation of Parallel (CUDA) algorithm to Add two large Vector, Multiply Vector and Matrix and Multiply two  $N \times N$  arrays using  $n^2$ .

**Outcome:** To offload parallel computations to the graphics card, when it is appropriate to do so, and to give some idea of how to think about code running in the massively parallel environment presented by today's graphics cards.

**Outcome:** Students should understand the basic of GPU computing in the CUDA environment.

**Prerequisites:** Strassen's Matrix Multiplication Algorithm and CUDA Tutorials.

**Hardware Specification:** x86\_64 bit, 2 – 2/4 GB DDR RAM, 80 - 500 GB SATA HD, 1GB NVIDIA TITAN X Graphics Card.

**Software Specification:** Ubuntu 14.04, GPU Driver 352.68, CUDA Toolkit 8.0, CUDNNLibrary v5.0

### Introduction:

It has become increasingly common to see supercomputing applications harness the massive parallelism of graphics cards (Graphics Processing Units or GPUs) to speed up computations. One platform for doing so is NVIDIA's Compute Unified Device Architecture (CUDA). We use the example of Matrix Multiplication to introduce the basics of GPU computing in the CUDA environment.

Matrix Multiplication is a fundamental building block for scientific computing. Moreover, the algorithmic patterns of matrix multiplication are representative. Many other algorithms share similar optimization techniques as matrix multiplication. Therefore, matrix multiplication is one of the most

important examples in learning parallel programming.

A kernel that allows host code to offload matrix multiplication to the GPU. The kernel function is shown below,

```
__global__ void MatMulKernel(Matrix A, Matrix B, Matrix C) {  
    // Each thread computes one element of C  
    // by accumulating results into Cvalue  
    float Cvalue = 0;  
    int row = blockIdx.y * blockDim.y + threadIdx.y;  
    int col = blockIdx.x * blockDim.x + threadIdx.x;  
    if(row > A.height || col > B.width) return;  
    for (int e = 0; e < A.width; ++e)  
        Cvalue += A.elements[row * A.width + e] *  
                  B.elements[e * B.width + col];  
    C.elements[row * C.width + col] = Cvalue;  
}
```

The first line contains the `__global__` keyword declaring that this is an entry-point function for running code on the device. The declaration `float Cvalue = 0` sets aside a register to hold this float value where we will accumulate the product of the row and column entries. The next two lines help the thread to discover its row and column within the matrix. It is a good idea to make sure you understand those two lines before moving on. The `if` statement in the next line terminates the thread if its row or column place it outside the bounds of the product matrix. This will happen only in those blocks that overhang either the right or bottom side of the matrix.

The next three lines loop over the entries of the row of **A** and the column of **B** (these have the same size) needed to compute the (row, col)-entry of the product, and the sum of these products are accumulated in the **Cvalue** variable. Matrices **A** and **B** are stored in the device's global memory in row major order, meaning that the matrix is stored as a one-dimensional array, with the first row followed by the second row, and so on. Thus to find the index in this linear array of the ( **i**, **j** ) entry of matrix **A**. Finally, the last line of the kernel copies this product into the appropriate element of the product matrix **C**, in the device's global memory.

In light of the memory hierarchy described above, each threads loads (  $2 \times \mathbf{A. width}$  ) Elements in Kernel .From global memory two for each iteration through the loop,one from matrix **A** and one from matrix **B**. Since accesses to global memory are relatively slow, this can bog down the kernel, leaving the threads idle for hundreds of clock cycles, for each access.

Matrix **A** is shown on the left and matrix **B** is shown at the top, with matrix **C**, their product, on the bottom-right. This is a nice way to lay out the matrices visually, since each element of **C** is the product of the row to its left in **A** and the column above it in **B**. In the above figure, square thread blocks of dimension **BLOCK\_SIZE**.

**BLOCK\_SIZE** and will assume that the dimensions of **A** and **B** are all multiples of **BLOCK\_SIZE**. Again, each thread will be responsible for computing one element of the product matrix **C**.

It decomposes matrices **A** and **B** into non-overlapping submatrices of size **BLOCK\_SIZE**  $\times$  **BLOCK\_SIZE**. It shows in above figure in red row and red column. It passesthrough the same number of these submatrices, since they are of equal length. If it load the left- most of those submatrices of matrix **A** into shared memory, and the top-most of those submatrices of matrix **B** into shared memory, then it compute the first **BLOCK\_SIZE** products and add them together just by reading the shared memory. But here is the benefit, as long as it have those submatrices in shared memory, every thread's thread block (computing the **BLOCK\_SIZE**  $\times$  **BLOCK\_SIZE** submatrix of **C**) can compute that portion of their sum as well from the same data in shared memory. When each thread has computed this sum, it loads the next **BLOCK\_SIZE**  $\times$  **BLOCK\_SIZE** submatrices from **A** and **B**, and continue adding the term-by-term products to our value in **C**.

- Applications:**
1. Fast Video Trans-coding & Enhancement.
  2. Medical Imaging.
  3. Neural Networks.
  4. Gate-level VLSI Simulation.

**Conclusion:** Strassen's Matrix Multiplication Algorithm have been implemented parallel using GPU computing in the CUDA environment

## Experiment 5

<b>Title</b>	Design & implementation of Parallel(OpenMP) algorithm for K-Nearest Neighbors Classifier.
<b>Problem statement</b>	Design & implementation of Parallel(OpenMP) algorithm for K-Nearest Neighbors Classifier.
<b>Prerequisite</b>	Data Structure and Files, Design and Analysis of Algorithm, Open MP Tutorials
<b>CO mapped</b>	4
<b>Programming Tools</b>	Ubuntu14.04,GEdit,GCCComplier

**Title:** Design & implementation of Parallel (OpenMP) algorithm for K-Nearest Neighbors Classifier.

**Objectives:** To off load parallel computation the graphics card, when it is appropriate to do so, and to give some idea of how to think about code running in the massively parallel environment presented by today's graphics cards.

**Outcome:** Students should understand the basic of OpenMP Programming Module using exiting K-Nearest Neighbors Classifier.

**Prerequisites:** Data Structure and Files, Design and Analysis of Algorithm, Open MP Tutorials.

**Hardware Specification:** x86\_64 bit,2– 2/4 GBDDR RAM, 80-500 GB SATAHD.

**SoftwareSpecification:**Ubuntu14.04, GEdit, GCC Complier.

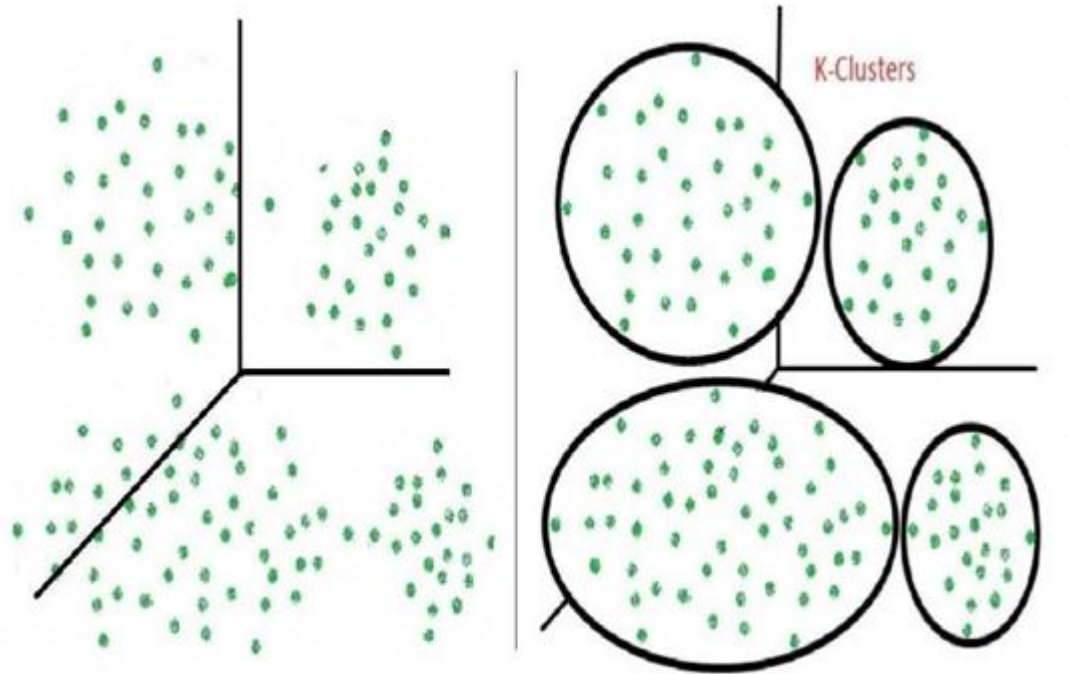
### Introduction:

An Application Program Interface (**API**) that may be used to explicitly direct multithreaded, shared memory parallelism. An Open Multi-Processing (**OpenMP**) consists of aset of compiler *#pragmas* that control how the program works. The **pragmas** are designed so that even if the compiler does not support them, the program will still yield correct behavior, but without any parallelism.

K-means is a popular clustering method because it is simple to program and is easy to compute on large samples . The k-means clustering algorithm classifies N vectors with d dimension into k clusters by assigning each vector to the cluster whose average value is nearest to it by some distance measure on that set. The algorithm computes iteratively, until reassigning points and recompiling averages reaches optimal value. Initially given k, total number of clusters, the training samples are assigned to k clusters randomly. Alternately the first k training sample can be considered as single-element cluster and then each of the remaining (N-k) training samples is assigned to the nearest cluster.

After each assignment, the cluster centers are recomputed as referred as centroid of the cluster. Again each sample is taken in a sequence and computed its distance from the centroid If a sample is not

currently in the cluster with the closest centroid, switch this sample to that cluster and update the centroid of the cluster gaining the new sample and the cluster losing the sample.



Repeat step 3 until convergence is achieved, that is until sample causes no new assignments. We calculate the distance to all centroid and get the minimum distance. At the termination of the K means algorithms all the points will belong to a cluster with shortest distance from its centroid. Above Figure, shows the clusters formed with number of points and 4 clusters.

### Applications:

1. In Wireless Sensor Network's based Application.
2. In Search Engines and Drug Activity Prediction.

**Conclusion:** We have tested both the Searching algorithms for K –clusters with respective to time. As the number of Clusters increased time required for OpenMP is reduced.