Assignment no 5

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Q. 1. Write a short note on the following.

1. The architecture of the PRAM model
2. Concurrent and exclusive memory access.

Solutions :

1- The Architecture of PRAM Model

1. It consists of a control unit, global memory, and an unbounded set of similar processors, each with their own private memory.
2. An active processor reads from global memory, performs required computation, and then writes to global memory.
3. Therefore, if there are N processors in a PRAM, then N number of independent operations can be performed in a particular unit of time.

2- concurrent and exclusive memory acesses

EREW: also called Exclusive Read Exclusive Write is a constraint which doesn't allow two processors to read or write from the same memory location at the same instance.

CREW: also called Concurrent Read Exclusive Write is a constraint which allows all the processors to read from the same memory location but are not allowed to write into the same memory location at the same time.

ERCW: also called Exclusive Read Concurrent Write is a constraint which allows all the processors to write to the same memory location but are now allowed to read the same memory location at the same time.

CRCW: also called Concurrent Read Concurrent Write is a constraint which allows all the processors to read from and write to the same memory location parallelly.

Q. 2 What is pointer jumping? Explainlist rank algorithm with an example.

Ans :

The **Jump pointer algorithm** is a design technique for parallel algorithms that operate on pointer structures, such as arrays or linked list. This algorithm is normally used to determine the root of the forest of a rooted tree. The jump pointer algorithm associates up to $\mathbf{log_2 n}$ pointers to each vertex of the tree. **These pointers are called jump pointers because they jump up the tree towards the root node of the tree.** In the jump pointer algorithm, we pre-process a tree so that one can able to answer the queries to find any parent of any node in the tree in time complexity of **O(log n)**

Algorithm

```
jump[k][j] =   it points 2^jth parent of k
             =  2^j-1th parent of (2^j-1th parent of k)
             =  jump[jump[i][j-1][j-1]
```

Eg.

```
Input: 0th parent of node 2
Output: 0th parent of node 2 is = 2

Input: 2th parent of node 4
Output: 2th parent of node 4 is = 2

Input: 3rd parent of node 8
Output: 3rd parent of node 8 is = 1
```

Q. 3. What is prefix computation? Explain list prefix algorithm.

Ans :

An important primitive for(data)parallel computing is the scan operation, also called pre x sum which takes an associated binary operator and an ordered set[a_1,…., a_n] of n elements and returns the ordered set

Algorithm

$$
\begin{array}{l}
\textbf{for } i \leftarrow 0 \textbf{ to } \lceil \log_2 n \rceil - 1 \textbf{ do} \\
\quad \textbf{for } j \leftarrow 0 \textbf{ to } n - 1 \textbf{ do in parallel} \\
\quad\quad \textbf{if } j < 2^i \textbf{ then} \\
\quad\quad\quad x_j^{i+1} \leftarrow x_j^i \\
\quad\quad \textbf{else} \\
\quad\quad\quad x_j^{i+1} \leftarrow x_j^i + x_{j-2^i}^i
\end{array}
$$

In the above, the notation x^i_j means the value of the *j*th element of array *x* in timestep *i*.

Given *n* processors to perform each iteration of the inner loop in constant time, the algorithm as a whole runs in *O*(log *n*) time, the number of iterations of the outer loop.

Q. 4. Write and Explain the algorithms of sequential and parallel summation of the array elements.

Ans :

1.Sequential summation algorithm

The summation algorithm based on finger search addresses all of the issues of the partial sum algorithm. Generally, it is more efficient, since its running time is logarithmic in the number of specified consecutive elements against the number of all of the elements in a sequence.The algorithm based on finger search does not sum up elements before the lower summation limit and, thus, provides basically the same accuracy of the result as the standard sequential summation. This advantage can be important in practice to minimize computational numerical errors. Compared to the partial sum algorithm, the summation algorithm based on finger search is more general. It can be applied to any consecutive elements in a sequence, not just the first ones.

2. Parallel summation algorithm

The ideal parallel summation algorithm achieves considerable performance gain by applying the divide and conquer technique, which avoids sequential processing of a large number of elements that has linear running time.The algorithm uses system processors to divide a given data set into pairs of adjacent elements. The sums of all of the pairs are computed simultaneously and become elements of a new data set to be processed at the next stage of the computations. Each stage of processing decreasesthe number of elements and involved processors by a factor of 2. The last stage computes the total sum of all of the elements in the given data set. The running time of this algorithm is determined by the number of stages, which is logarithmic in the number of elements.

Q. 5. What is a parallel prefix? Explain any one parallel prefix algorithm.

Ans:

Prefix: The outcome of the operation depends on the initial inputs.

Parallel: Involves the execution of an operation in parallel. This is done by segmentation into smaller pieces that are computed in parallel.

Operation: Any arbitrary primitive operator " ° " that is associative is parallelizable

Algorithm

- Compute the sums of consecutive pairs of items in which the first item of the pair has an even index: $z_0 = x_0 + x_1$, $z_1 = x_2 + x_3$, etc.
- Recursively compute the prefix sum $w_0, w_1, w_2, \ldots$ of the sequence $z_0, z_1, z_2, \ldots$
- Express each term of the final sequence $y_0, y_1, y_2, \ldots$ as the sum of up to two terms of these intermediate sequences: $y_0 = x_0$, $y_1 = z_0$, $y_2 = z_0 + x_2$, $y_3 = w_0$, etc. After the first value, each successive number y_i is either copied from a position half as far through the w sequence

Q. 6. Explain CRCW algorithm for finding maximum of n array elements.

Ans :

Finding Maximum: CRCW Algorithm

Given n elements A[0, n-1], find the maximum.
With n^2 processors, each processor (i,j) compare A[i] and A[j], for $0 \le i, j \le n-1$.

FAST-MAX(A):

```
n←length[A]
for i ←0 to n-1, in parallel
    do m[i] ←true
for i ←0 to n-1 and j ←0 to n-1, in parallel
    do if A[i] < A[j]
        then m[i] ←false
for i ←0 to n-1, in parallel
    do if m[i] =true
        then max ← A[i]
return max
```

$A[i]$ \ $A[j]$	5	6	9	2	9	m
5	F	T	T	F	T	F
6	F	F	T	F	T	F
9	F	F	F	F	F	T
2	T	T	T	F	T	F
9	F	F	F	F	F	T

max=9

The running time is $O(1)$.

Note: there may be multiple maximum values, so their processors Will write to max concurrently. Its $work = n^2 \times O(1) = O(n^2)$.

Q. 7. Write a note on Flynn's classification.

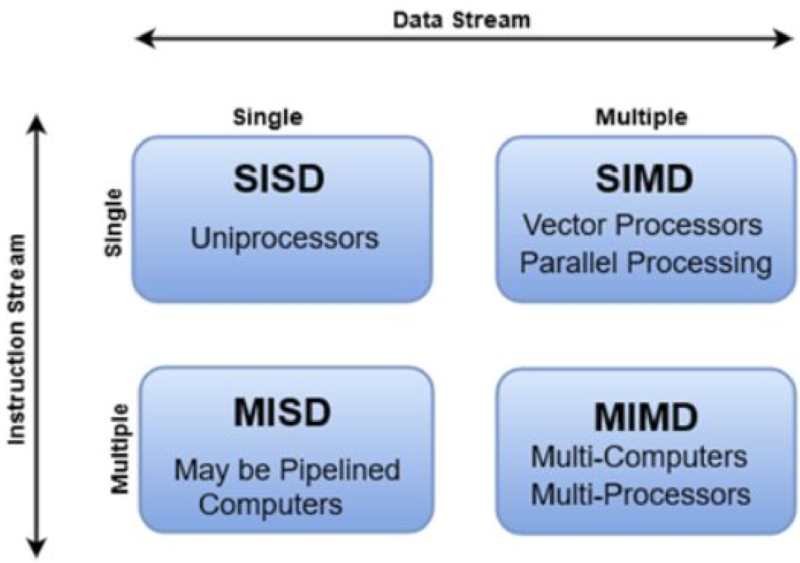
Ans:

M.J. Flynn proposed a classification for the organization of a computer system by the number of instructions and data items that are manipulated simultaneously.

The sequence of instructions read from memory constitutes an **instruction stream**.

The operations performed on the data in the processor constitute a **data stream**.

Flynn's Classification of Computers



Q. 8. Explain EREW PRAM algorithm of sorting n elements of an array.

Ans:

List ranking –EREW algorithm

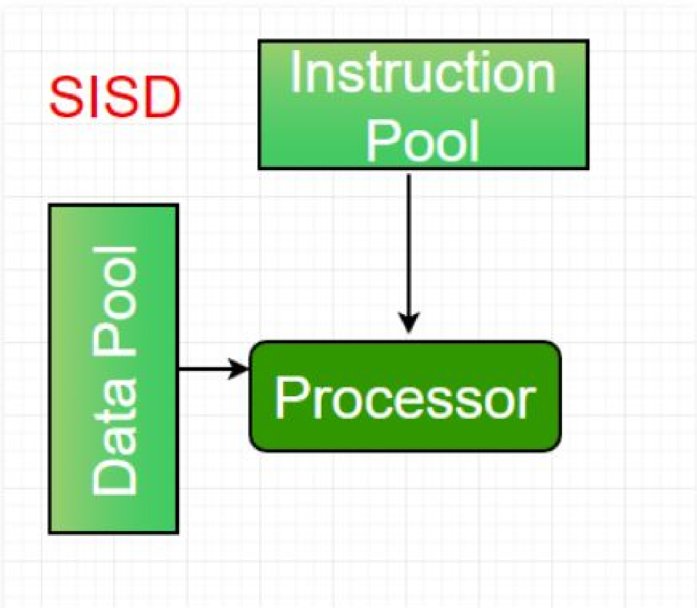
- LIST-RANK(L)   (in O(lg n) time)

```
for each processor i, in parallel
    do if next[i]=nil
        then d[i]←0
        else d[i]←1
while there exists an object i such that next[i]≠nil
    do for  each processor i, in parallel
        do if next[i]≠nil
            then d[i]← d[i]+ d[next[i]]
                 next[i] ←next[next[i]]
```

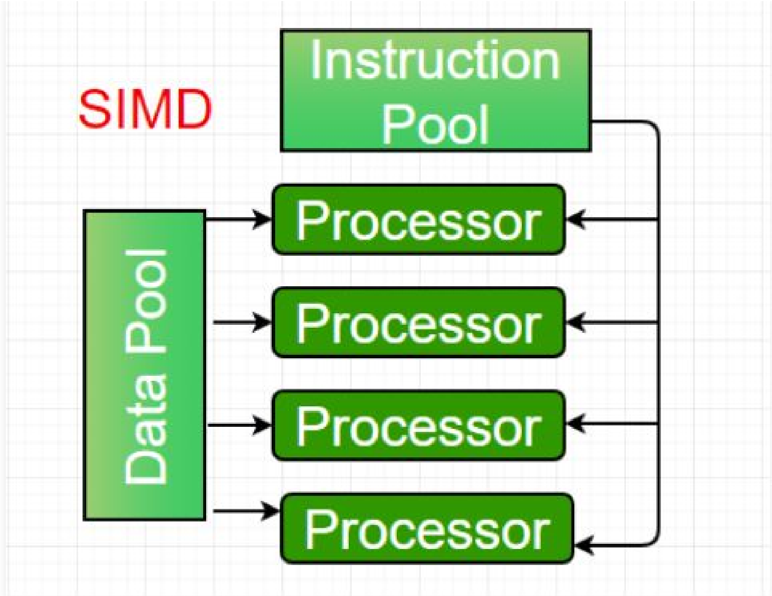
Q. 9. Write a note on the following:

1. SISD and SIMD
2. MISD and MIMD

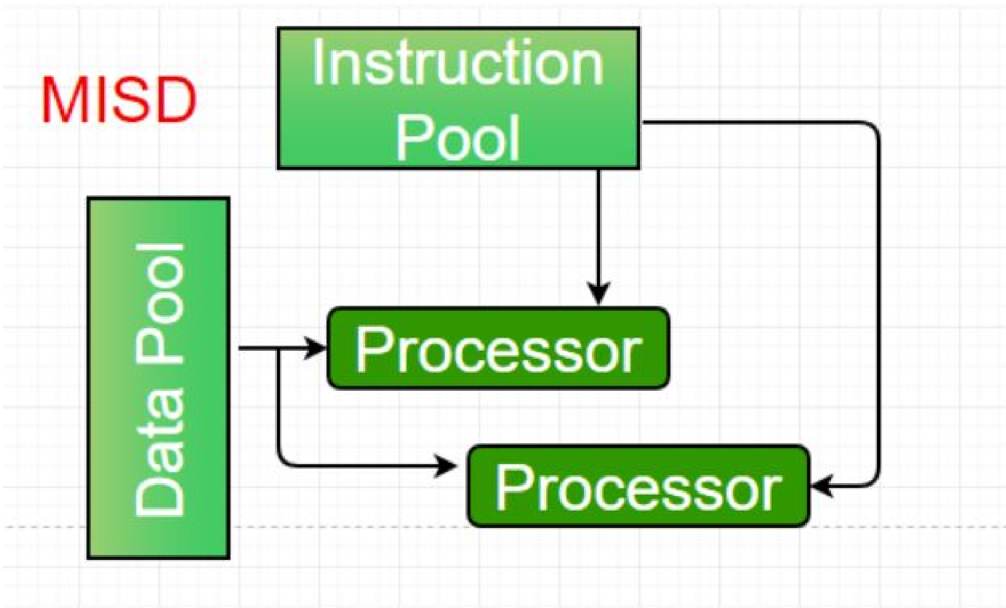
Single-instruction, single-data (SISD) systems –
An SISD computing system is a uniprocessor machine which is capable of executing a single instruction, operating on a single data stream.



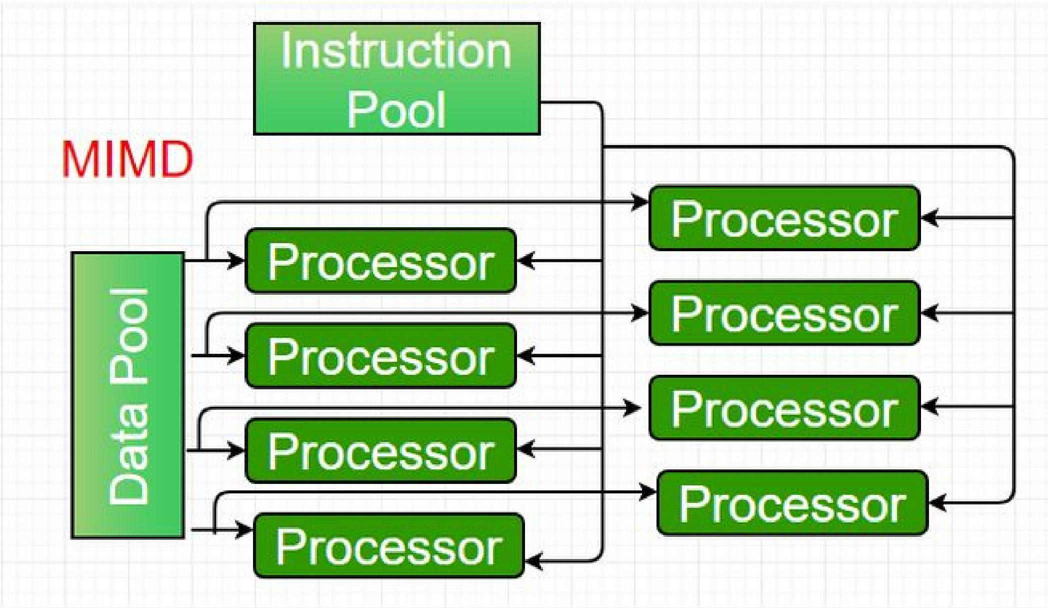
Single-instruction, multiple-data (SIMD) systems –
An SIMD system is a multiprocessor machine capable of executing the same instruction on all the CPUs but operating on different data streams. Machines based on an SIMD model are well suited to scientific computing since they involve lots of vector and matrix operations.



Multiple-instruction, single-data (MISD) systems –
An MISD computing system is a multiprocessor machine capable of executing different instructions on different PEs but all of them operating on the same dataset .



Multiple-instruction, multiple-data (MIMD) systems –
An MIMD system is a multiprocessor machine which is capable of executing multiple instructions on multiple data sets. Each PE in the MIMD model has separate instruction and data streams; therefore machines built using this model are capable to any kind of application.



MIMD
Instruction Pool
Data Pool
Processor
Processor
Processor
Processor
Processor
Processor
Processor
Processor