National Institute of Technology Karnataka Surathkal
Department of Information Technology

IT 301 Parallel Computing

Shared Memory Programming Technique (6)

OpenMP : *sections, threadprivate, collapse*

Dr. Geetha V
Assistant Professor
Dept of Information Technology
NITK Surathkal

Index

- OpenMP
    - Directives : if, for, master, single, Barrier, atomic, critical,
    - Directives
        - Sections
    - Clauses
        - Threadprivate
        - Collapse
        - Threadwait
        - Copyin, copyprivate
- References

Course Outline

Course Plan: Theory:

Part A: Parallel Computer Architectures

Week 1,2,3: ***Introduction to Parallel Computer Architecture:*** Parallel Computing, Parallel architecture, bit level, instruction level , data level and task level parallelism. Instruction level parelllelism: pipelining(Data and control instructions), scalar and superscalar processors, vector processors. Parallel computers and computation.

Week 4,5: Memory Models: UMA, NUMA and COMA. Flynns classification, Cache coherence,

Week 6,7: Amdahl's Law. Performance evaluation, Designing parallel algorithms : Divide and conquer, Load balancing, Pipelining.

Week 8 -11: ***Parallel Programming techniques like Task Parallelism using TBB, TL2, Cilk++ etc. and software transactional memory techniques.***

Course Outline

Part B: OpenMP/MPI/CUDA

Week 1,2,3 : ***Shared Memory Programing Techniques:*** Introduction to OpenMP : Directives: *parallel, for, sections, task, master, single, critical, barrier, taskwait, atomic. Clauses: private, shared, firstprivate, lastprivate, reduction, nowait, ordered, schedule, collapse, num_threads, if(), threadprivate, copyin, copyprivate*

Week 4,5: ***Distributed Memory programming Techniques:*** MPI: Blocking, Non-blocking.

Week 6,7 : CUDA : OpenCL, Execution models, GPU memory, GPU libraries.

Week 10,11,: ***Introduction to accelerator programming using CUDA/OpenCL and Xeon-phi. Concepts of Heterogeneous programming techniques.***

Practical:

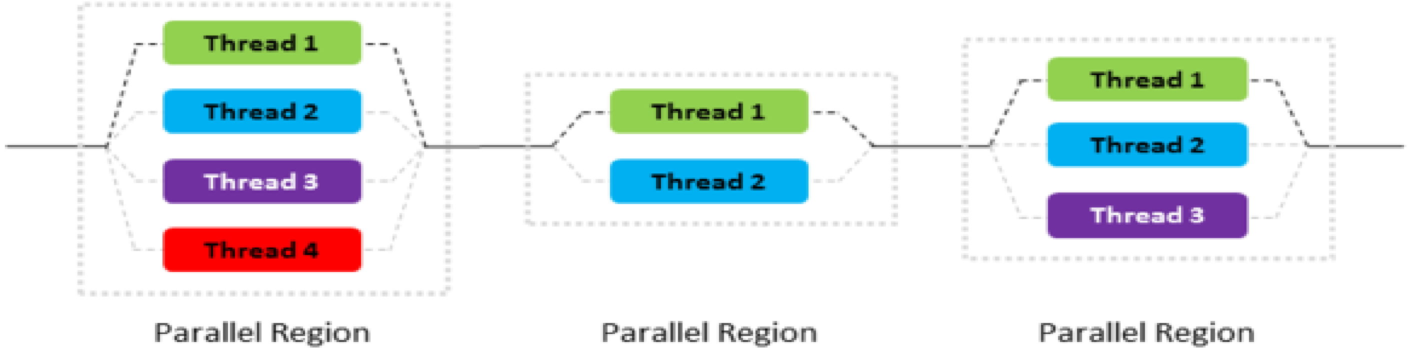
Implementation of parallel programs using OpenMP/MPI/CUDA.

Assignment: Performance evaluation of parallel algorithms (in group of 2 or 3 members)

1. OpenMP

FORK – JOIN Parallelism

- OpenMP program begin as a single process: the master thread. The master thread executes sequentially until the first parallel region construct is encountered.
- When a parallel region is encountered, master thread
  - – Create a group of threads by FORK.
  - – Becomes the master of this group of threads and is assigned the thread id 0 within the group.
- The statement in the program that are enclosed by the parallel region construct are then executed in parallel among these threads.
- JOIN: When the threads complete executing the statement in the parallel region construct, they synchronize and terminate, leaving only the master thread.



2. OpenMP Programming: Worksharing

Work sharing constructs

- Loop constructs
- Section construct
- Single construct

2. OpenMP Programming: Section

```
#pragma omp sections [clause,….]
{
 [#pragma omp section new-line
   Structured block]
 [#pragma omp section new-line
   Structured-block]
```

Clauses

Private(list)

Firstprivate(list)

Lastprivate(list)

Reduction(operator:list)

nowait

Section :

- It is a non-iterative work-sharing construct that contains a set of structured blocks that are to be divided among, and executed by, the threads in a team.
- Each structured block is executed by one of the threads in the team.
- There is an implicit barrier at the end of sections construct, unless a *nowait* clause is specified.
- Only a single *nowait* clause can appear on a sections directive.

2. OpenMP Programming: Collapse

```
#pragma omp for schedule(static, n)
collapse(2)
for(i=0; i<imax; i++) {
  for(j=0; j<jmax;j ++)
      a[i][j] = b[i][j] + c[i][j]
}
```

Collapse :

- It increases the total number of iterations that will be partitioned across the available number of OMP threads by reducing the granularity of work to be done by each thread.
- If the amount of work to be done by each thread is non-trivial (after collapsing is applied), this may improve the parallel scalability of the OMP applications.

2. OpenMP Programming: threadprivate

```
#pragma omp threadprivate(list)
```

Threadprivate

- Each thread is allowed to have its own temporary view of the shared memory.
- Each thread also has access to another type of memory that must not be accessed by other threads , called threadrivate memory
- **Shared variable**: each thread refers to the original variable.
- **Private variable:** Current thread's private version of the original variable.
- **Threadprivate**: variable appearing in threadprivae directives are threadprivate.

2. OpenMP Programming: threadprivate

```
#pragma omp threadprivate(list)
```

Threadprivate

- It specifies that named global-lifetime objects are replicated, with each thread having is own copy.
- Each copy of the *threadprivate* object is initialized once.
- A thread may not reference another thread's copy of a *threadprivate* object.
- A *threadprivate* object must not appear in any clause except the *copyin*, *copyprivate*, *schedule*, *num_threads*, and *if* clauses.
- The list is a comma-separated list of file-scope, names-scope, or static block-scope variables that do not have incomplete types.

2. OpenMP Programming: threadprivate

```
#pragma omp threadprivate(list)
```

Private vs Threadprivate

- Private variable scope is defined for only specific parallel region. *Threadprivate* is variable scope is declared across the parallel regions.
- *Firstprivate()* is used to copy the values from original variable. *Copyin()* is used to copy the values while entering into parallel region first time.
- Private variables are stored on stack most of the time. *Threadprivate* variables are stored in heap or thread local storage.

2. OpenMP Programming: threadprivate

```
#pragma omp threadprivate(list)


Copyin(list)
Copyprivate(list)
```

Data Copying clauses

- These clauses support the copying of data values from private or *threadprivate* variables on one implicit task or thread to the corresponding variables on other implicit tasks or threads in the team.
- **Copyin(list):** Copies the value of the master thread's *threadprivate* variable to the *threadprivate* variable of each other member of the team executing the parallel region.
- **Copyprivate (list)** : Broadcasts a value from the data environment of one implicit task to the data environments of the other implicit tasks belonging to the parallel region.

Index

- OpenMP
  - Directives : if, for, master, single, Barrier, atomic, critical,
  - Directives
    - Sections
  - Clauses
    - Threadprivate
    - Collapse
    - Threadwait
    - Copyin, copyprivate
- References

Reference

Text Books and/or Reference Books:

1. Professional CUDA C Programming – John Cheng, Max Grossman, Ty McKercher, 2014

2. B.Wilkinson, M.Allen, ”Parallel Programming: Techniques and Applications Using Networked Workstations and Parallel Computers”, Pearson Education, 1999

3. I.Foster, ”Designing and building parallel programs”, 2003

4. Parallel Programming in C using OpenMP and MPI – Micheal J Quinn, 2004

5. Introduction to Parallel Programming – Peter S Pacheco, Morgan Kaufmann Publishers, 2011

6. Advanced Computer Architectures: A design approach, Dezso Sima, Terence Fountain, Peter Kacsuk, 2002

7. Parallel Computer Architecture : A hardware/Software Approach, David E Culler, Jaswinder Pal Singh Anoop Gupta, 2011 8. Introduction to Parallel Computing, Ananth Grama, Anshul Gupta, George Karypis, Vipin Kumar, Pearson, 2011

Reference

Acknowledgements

1. Introduction to OpenMP https://www3.nd.edu/~zxu2/acms60212-40212/Lec-12-OpenMP.pdf

2. Introduction to parallel programming for shared memory Machines https://www.youtube.com/watch?v=LL3TAHpxOig

3. OpenMP Application Program Interface Version 2.5 May 2005

4. OpenMP Application Program Interface Version 5.0 November 2018

Thank You