C-DAC Four Days Technology Workshop

ON

Hybrid Computing – Coprocessors/Accelerators
Power-Aware Computing – Performance of Applications Kernels

hyPACK-2013
(Mode-1:Multi-Core)

Lecture Topic:

Multi-Core Processors : Shared Memory Prog: An Overview of Intel Thread Building Blocks (TBB)

Venue : CMSD, UoHYD ; Date : October 15-18, 2013

An Overview of Intel Thread Building Blocks

Lecture Outline

Following topics will be discussed

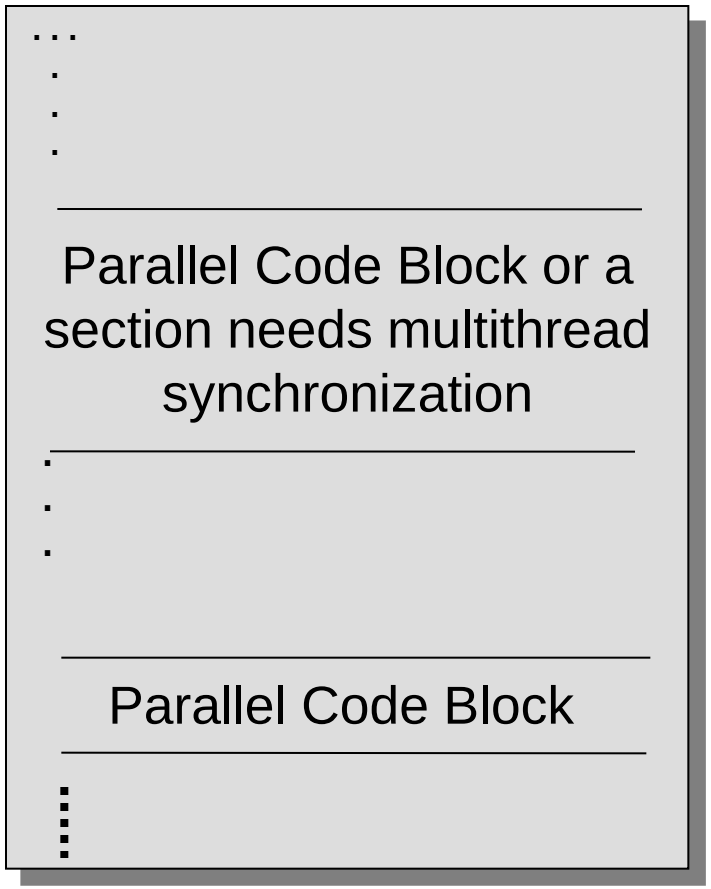
- Why Thread Building Blocks (TBB) ?
- Summary of high-level templates Loops - Loop Parallelization
- Algorithms templates – Intel TBB
- Memory Allocation – TBB – Performance Issues
- TBB Task Scheduler – Speed-Up issues
- TBB Application Perspective

Part II

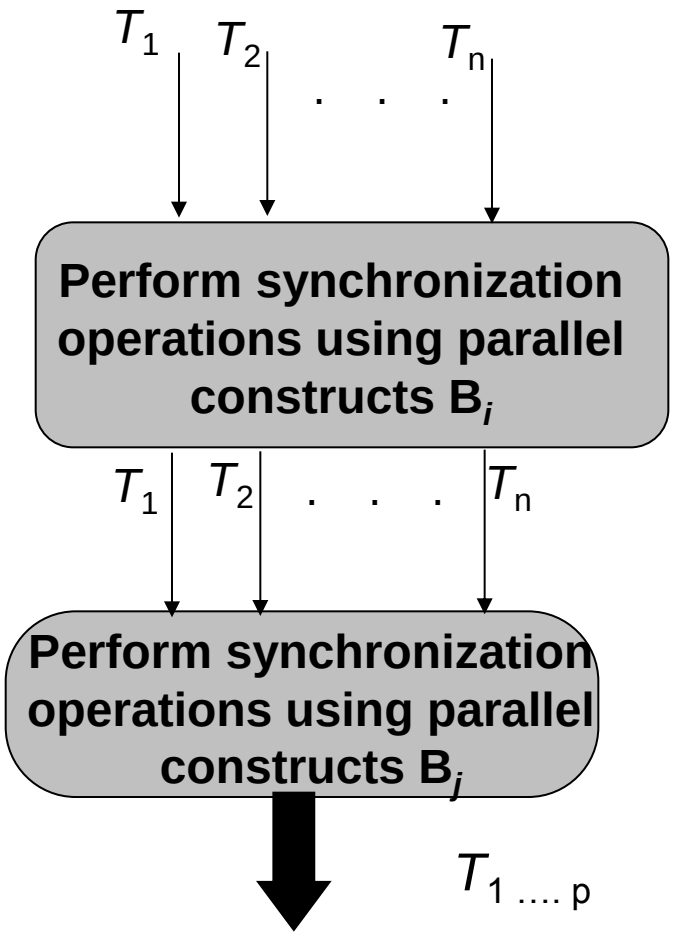
Intel TBB

Background : Operational Flow of Threads for an Application

Implementation Source Code

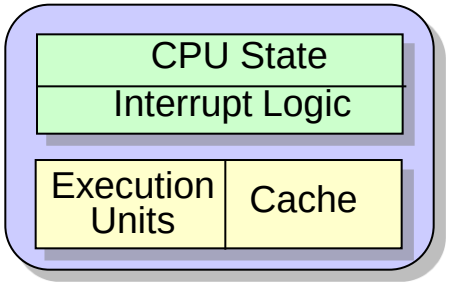


Operational Flow of Threads

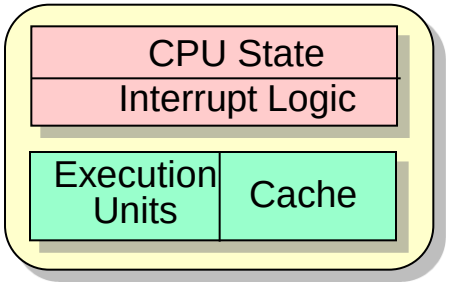


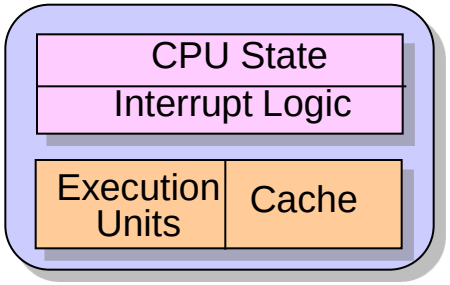
Source : http://www.intel.com ; Reference : [6]

Simple Comparison of Single-core, Multi-processor, and Multi-core Architectures

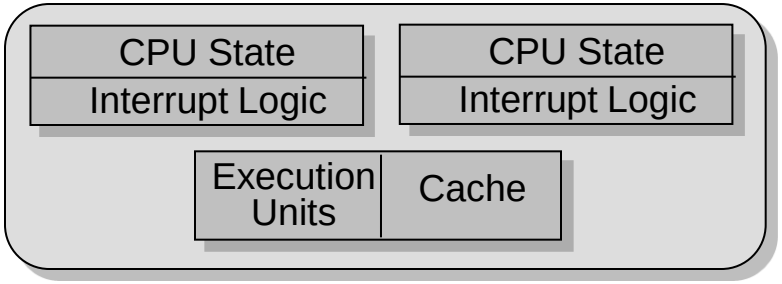


A) Single Core

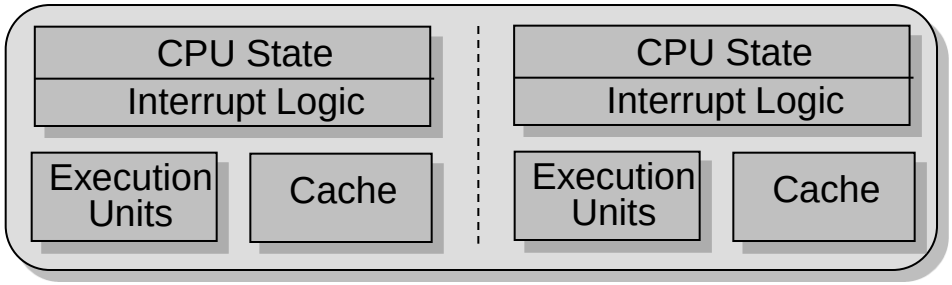


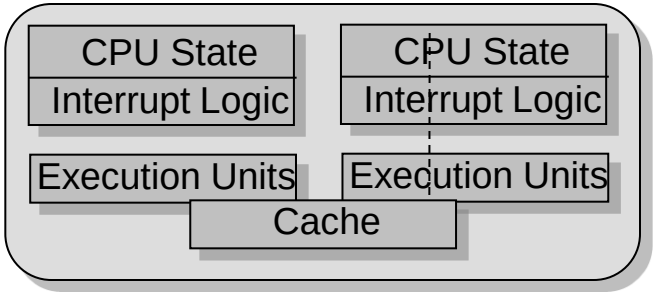


B) Multi Processor

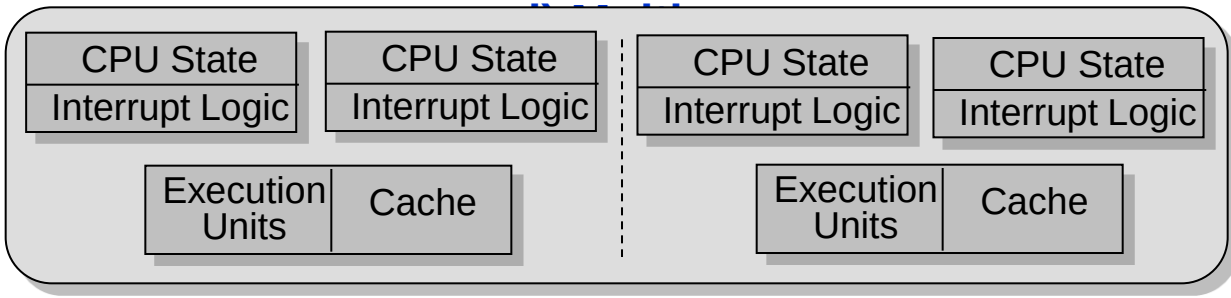


C) Hyper-Threading Technology





E) Multi-core with Shared Cache



F) Multi-core with Hyper-threading Technology

Source : http://www.intel.com ; Reference : [6], [29], [31]

Multi Core : Programming Issues

- Out of Order Execution
- Pre-emptive and Co-operative Multitasking
- SMP to the rescue
- Super threading with Multi threaded Processor
- Hyper threading the next step (Implementation)
- Multitasking
- Caching and SMT

Part II

Application Perspective

Multi Cores - Unique Challenges

TBB can be targeted for ease of development

Issues to be Addressed

Bigger *OR* Smaller Cores

Performance OR Scalability

Compute *OR* I/O Intensive

Cache Friendly OR Memory Intensive

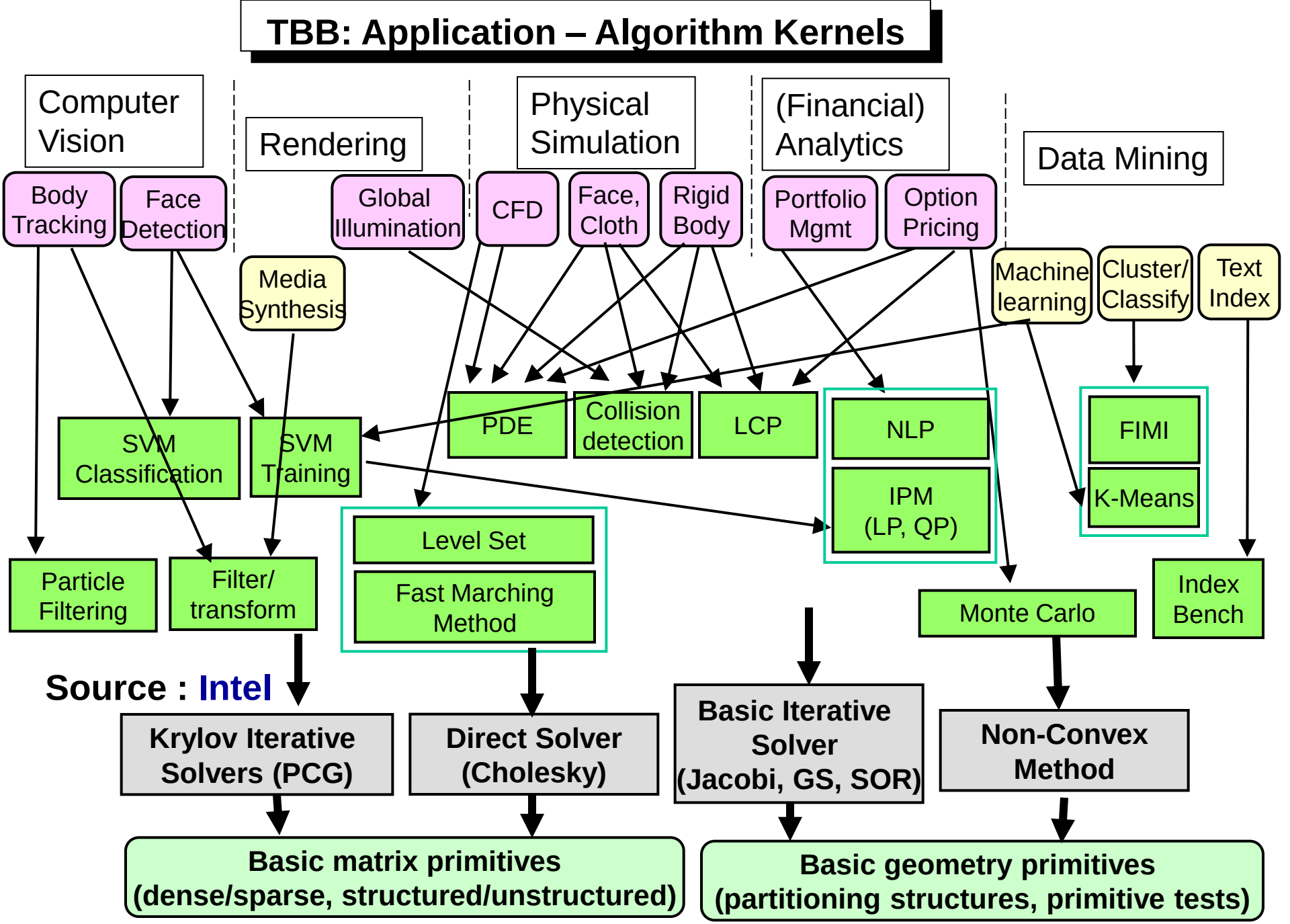
Source : http://www.intel.com ; Reference : [6]

Emerging "Killer Apps of Tomorrow" Parallel Algorithms Design

Use of TBB : Several Class of Applications

- Video : Body Tracking and Ray-Tracing
- Search for Video based imaging & Creation of Videos with animation
- Games / Interactive 3D simulation
- Real-time realistic 3D Visualization of body systems
- Wall Street Financial Analysis; Business: Data Mining – Security: Real Time Video surveillance Astrophysics,
- BioInformatics – Pattern Search Algorithms

TBB: Application – Algorithm Kernels



Programming Aspects Examples

TBB : Other Issues to be addressed

Example : Implementation of Streaming Media Player on Multi-Core

- One decomposition of work using Multi-threads
- It consists of
  - A thread Monitoring a network port for arriving data,
  - A decompressor thread for decompressing packets
  - Generating frames in a video sequence
  - A rendering thread that displays frame at programmed intervals

Source : Reference : [4]

Programming Aspects Examples

Example : Implementation of Streaming Media Player on Multi-Core

- The thread must communicate via shared buffers –
  - an in-buffer between the network and decompressor,
  - an out-buffer between the decompressor and renderer
- It consists of
  - Listen to port ……..Gather data from the network
  - Thread generates frames with random bytes (Random string of specific bytes)
  - Render threads pick-up frames & from the out-buffer and calls the display function
  - Implement using the Thread Condition Variables

Killer Apps of Tomorrow

TBB: Application-Driven Architectures:Analyzing Workloads

- Workload convergence
  - The basic algorithms shared by these high-end workloads
- Platform implications
  - How workload analysis guides future architectures
- Programmer productivity
  - Optimized architectures will ease the development of software
- Call to Action
  - Benchmark suites in critical need for redress

Why Threading Building Blocks ?

Benefits

- Easy way to express parallelism in a C++ Program
  - Library that helps to you leverage Multi-core processor performance
  - No need of having threading expert for parallelisztion
  - High Level, tasks-based paralleism - for Performance and Scalability

Part III

TBB : Algorithms - Templates

Threading Building Blocks – Overview

Benefits

- Provides rich set of templates
  - Templates and C++ concept of generic programming (C++ Standard Template Library (STL)
- Doe not require special language or compilers
- Ability to use Threading Building Blocks – any processor with any C++ Complier
- Promote Scalable Data Parallelism

Threading Building Blocks – Overview

Benefits

- Scalability
  - Data Parallel Programming – Applications
  - Take advantage of all cores on Multi core Processor
- Specify Tasks instead of Threads
  - Runtime library
  - Automatically schedules tasks onto threads
  - Makes use of efficient processor resources
  - Load balancing many tasks

Threading Building Blocks - Overview

Benefits

- Task Scheduling
  - To use TBB library, you specify tasks, not threads
- Library maps tasks onto threads in an efficient manner
  - Writing Parallel_for loop – tedious using threading packages
  - Scalable program – harder ; No benefits in Performance
- Templates can give a creditable idea of performance with respect to problem size as the number of core increases

Thread Building Blocks – Overview

Benefits

- Better portability
- Easier programming,
- More understandable source code,
- Scalability and Performance – can be predicted
- Avoid programming in a raw native thread model

Remarks :

- Programming in assembly language of parallel programming -
  - An alternative use of raw threads.
  - Maximum flexibility – Costs are very high

Threading Building Blocks – Overview

Summary

- TBB enables developer to specify tasks instead of threads
- TBB targets threading for performance on Multi-cores
- TBB Compatible with other threading packages
- TBB emphasizes scalable, data-parallel programming
- Link libraries such as Intel's Math Kernel Library (MKL) and Integrated Performance Primitives (IPP) library are implemented internally using OpenMP.
  - You can freely link a program using Threading Building Blocks with the Intel MKL or Intel IPP library.

Threading Building Blocks – Overview

Issues to be Addressed

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Application Perspective - Parallel Algorithms Design -TBB

How TBB can hide several task Scheduling events ?

- Static Load Balancing
  - Mapping for load balancing
  - Minimizing Interaction
- Data Sharing Overheads
- Dynamic Load Balancing
  - Overheads in parallel algorithms design

Application Perspective - Parallel Algorithms Design -TBB

How TBB can hide several task Scheduling events ?

- Maximize data locality
- Minimize volume of data
- Minimize frequency of Interactions
- Overlapping computations with interactions.
  - Data replication
  - Minimize construction and Hot spots.
  - Use highly optimized collective interaction operations.
    - Collective data transfers and computations
  - Maximize Concurrency.

Types of Parallelism

TBB : Other Issues to be addressed

Types of Parallelism :

- Data parallelism and Task parallelism
- Combination of Data & Task parallelism
- Stream parallelism

TBB templates

- Initializing and Terminating the Library
- Loop Paralleization
  - Parallel_for, Parallel_reduce, Parallel_scan (Grain size, Interval, Workload for iteration, Time Taken)
  - Automatic Grain Size (Not easy) – Performance Issues
  - Recursive Range Specifications (block_range), Partitioning

TBB templates- Advanced Algorithms

- parallel_while
  - Use of an unstructured stream or pile of work. Offers the ability to add additional work to the file running
- pipeline (Throughput of pipeline)
- Parallel_sort
  - Algorithm complexity
- Parallel algorithms for Streams

TBB templates- Advanced Algorithms

- Containers
  - TBB provides highly concurrent containers that permit multiple threads to invoke a method simultaneously on the same container.
  - Concurrent queue, vector, and hash map are provided.
  - These can be used with the library, OpenMP, or raw threads
- Remark : Highly concurrent containers are very important because STL containers generally are not concurrent friendly.
- TBB provides Fine-grain locking and Lock free algorithm
  - Algorithm complexity
- Parallel algorithms for Streams

TBB Scalable Memory Allocation

- Problems in Memory Allocation
  - Each Competes for global lock for each allocation and deallocation from a single global heap
  - False Sharing
- TBB offers two memory allocators
  - Scalable_allocator
  - Cache_aligned_allocator
- Memory Consistency and Fence
- TBB provides atomic Templates

TBB Mutual Exclusion / Time

- TBB - Mutex
  - Mutual exclusion will be in terms of tasks. Mutual exclusion of tasks will lead to mutual exclusion of the corresponding threads upon which TBB maps defined tasks.
  - When to Use Mutual Exclusion (To prevent race conditions and other non-deterministic and undesirable behavior of tasks)
  - Mutex behavior
- TBB provides a thread-safe and portable method to compute elapsed time
  - tick_count Class

TBB Task Scheduler

- TBB - Task-based programming can improve the performance
  - Task Scheduler manages a thread pool and hides complexity which is much better than Raw Native Threads
  - OverSubscription – Getting the number of threads right is difficult
  - Fair Scheduling – OS uses; round-robin fashion
- Load imbalance can be handled easily comparison to thread-based programming
- Portability – TBB interfaces

Intel TBB conclusions

- An Overview of TBB on Multi Cores is discussed
- TBB algorithm templates can be used
- TBB memory allocator may help to reduce the memory overheads
- TBB can improve the performance for certain class of applications on 2/4/8/24 cores
- TBB Codes can be plugged with different libraries (Use only thread-safe libraries in your TBB application)
- Intel Tools can be used for debugging the TBB application.
- TBB can be used for several Data Parallel Applications.

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Thank You

Any questions ?