Parallel Programming

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Parallel Programming?

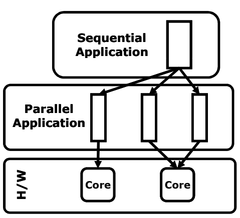
I still want to divide the effort of eating pizza to eat all slices as fast as possible!!

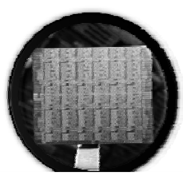
But, I wonder...

How we split this hard task ☺

Why Parallel Programming?

- Applications are naturally parallel
- Multi-core are out there
- We need to think in parallel!!!!





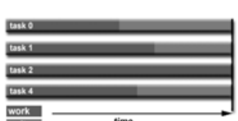
48- IA cores in the Intel "Single-chip Cloud Computer"

Agenda

- Motivation
- Designing Parallel Applications
- Parallel Programming Models
- Automatic Parallelization
- Parallel Programming for Games
- Concluding Remarks

Design of Parallel Applications

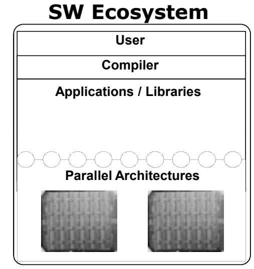
- Understand the Problem
  - Identify hotspots
    - Profile application
  - Identify bottlenecks to the parallelization
    - Communication
    - Synchronization
  - Consider alternative versions of the application
- Split Application in Parts
  - Maximum parallelism
  - Minimum imbalance
  - Minimum waiting time



Who Creates Parallel Applications?

- User/ Programmer
  - Parallel languages and libraries
- Compilers
  - Automatic Parallelization
- Parallel Architectures
  - Multi-core in a single chip
  - Many multi-core chips

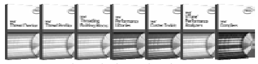
SW Ecosystem



What Do We Need?

Parallel Programming Languages — Intel Software Products; Intel Ct

Provide Tools Today — Architect, Thread, Debug & Tune; Intel Software Products

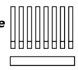


www.intel.com/software/products

Research Tomorrow's Techniques

Transactional Memory

Speculative Multi-threading



Data Parallel Languages

Educate Tomorrow's Experts

University Outreach
Intel ® Press
Intel® Software College

- *Helped 45 universities add parallel programming courses*
- *7500 students took them*
- *2007 Goal: 400+ universities*

When to Parallelize an Application?

- **Allways!!!!**
- Stop thinking in sequential applications
- Multicore era is here and we have to leverage the computing capabilities that we have out there

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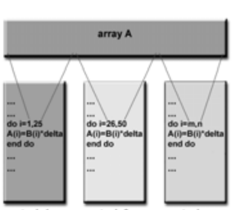
Parallel Programming Models

- Data Parallel
- Message Passing
- Shared Memory
- Distributed Shared Memory Model
- NOTE: These models are orthogonal to the actual hardware!!!

Data Parallel Model

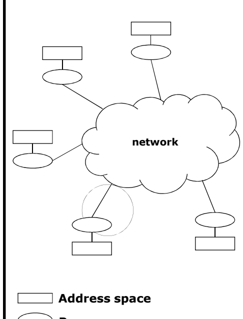


•Set of cooperating tasks on the same data structure
•Tasks perform the same operation over on different data items

Advantage
    Easy to write and comprehend
    No synchronization
Disadvantage
    No independent code

Example: HPF(High Performance Fortran)

Message Passing Model

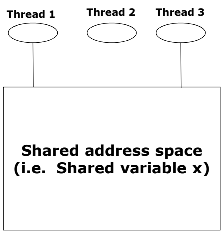


•A set of cooperating sequential processes
•Each with own local address space
•Processes interact with explicit transaction (send, receive,…)

Advantage
    Programmer controls data and work distribution
Disadvantage
    Communication overhead for small transactions
    Hard to program!

Example: MPI

Shared Memory Model



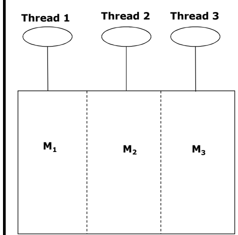
- Different simultaneous execution threads (processes)
- Read / Write to one shared memory space and invalidate if necessary

Advantage
- Read remote memory via an expression
- Write remote memory through assignment

Disadvantage
- Manipulating shared data leads to synchronization requirements
- Does not allow locality exploitation

Example : OpenMP

Distributed Shared Memory Model



Partitioned shared address space

(with each partition having affinity to corresponding thread)

- Similar to the shared memory paradigm
- Memory M_i has *affinity* to Thread i
- At the same time each thread has global view of memory

Advantage
- Helps exploiting locality of references
- Simple statements as SM

Disadvantage
- Synchronization still necessary

Example: UPC,Titanium,Co-Array,Global Arrays

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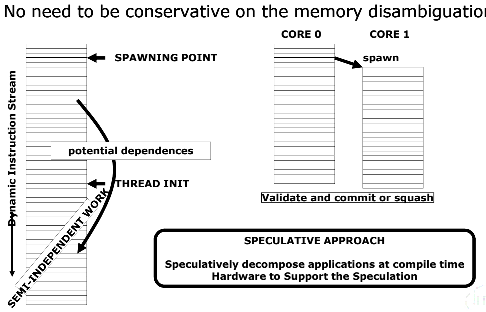
Traditional Auto Parallelization

- Automatic decomposition of applications into threads
- No need for inserting directives or pragmas
- Compiler identifies suitable parts of the application for parallelization
  - Typically simple loops
  - Considering simple memory disambiguation schemes
- This approach is typically limited to simple applications
  - Dependences limit its applicability to large scale applications

Speculative Multithreading

- Automatic decomposition of applications into speculative threads
  - No need to be conservative on the memory disambiguation



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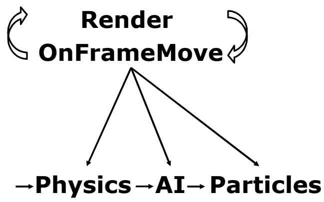
Usual Game Structure



Usual Game Structure

Render→Physics→AI→ Particles

http://softwarecommunity.intel.com/articles/eng/1363.htm

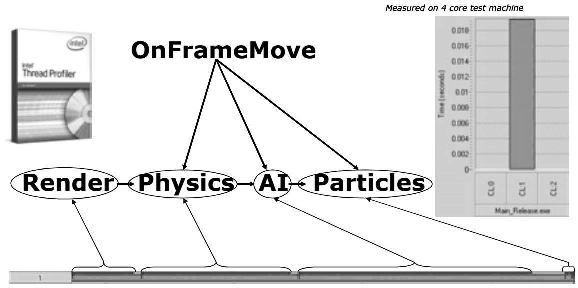
Game Thread Profiling

Sequential execution

25% of system utilization

Benchmark: 20.95sec

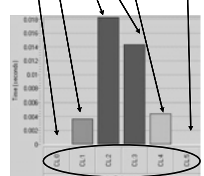
Measured on 4 core test machine

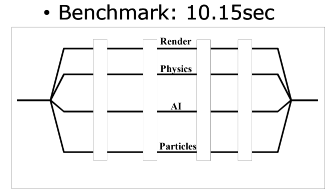


Functional Decompostion

Idle: no active threads
Serial: a single thread
Under-subscribed: # threads > 1 && # threads < # cores
Fully-subscribed: # threads == # cores
Oversubscribed: # threads > # cores

- **Load imbalance**
- Benchmark: 10.15sec



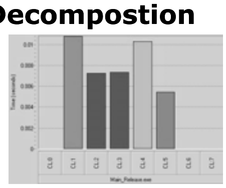


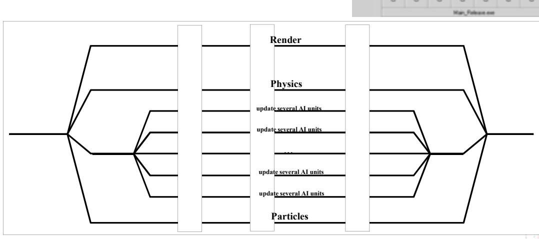
Concurrency level is the number of threads that are *active* (not waiting, sleeping, blocked, etc.) at a given time

Functional and Data Decompostion

- If Split AI in 2 threads
- **Load imbalance**
- Benchmark: 9.44sec

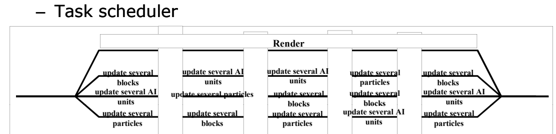
Measured on 4 core test machine

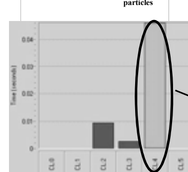




Intel® Threading Building Blocks

- Open Source Library for parallelism in C++
  - Fine-grain decomposition
  - Task scheduler





Good utilization of 4 cores
Benchmark: 8.66 sec

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Summary - Conclusions

- Parallel Applications are required to leverage Parallel Architectures
- Today we discussed about:
  - Why we need parallel applications
  - Considerations When Designing parallel applications
  - Parallel Programming Models
  - Auto Parallelization and Speculative Multithreading
  - The importance of threading in gaming
- We need to think in parallel to create parallel applications!!!

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