Exploiting Simultaneous Multi-threading for Parallel Mesh Generation on Intel HT Processors

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1 Motivation

• Quality mesh generation is a computationally intensive application. Parallel mesh generation (PCDT) [1] is a realistic solution for real-world problems, which are modeled with millions or billions of elements.

• Best sequential mesh generator : Triangle [2]

• However:

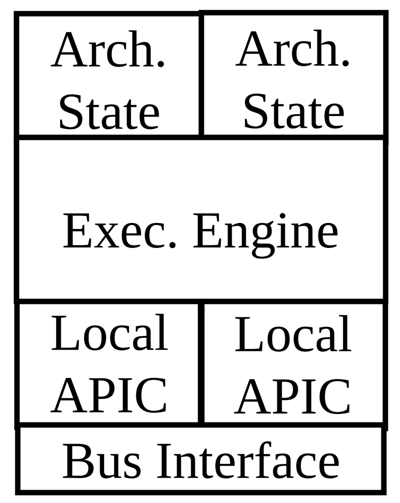
  • We do not have the time and resources to optimize single node parallel mesh generation so that it is comparable to the best sequential algorithm.

  • SMT processors offer a cost-effective alternative:

    • They often come for free (i.e. Intel HT)

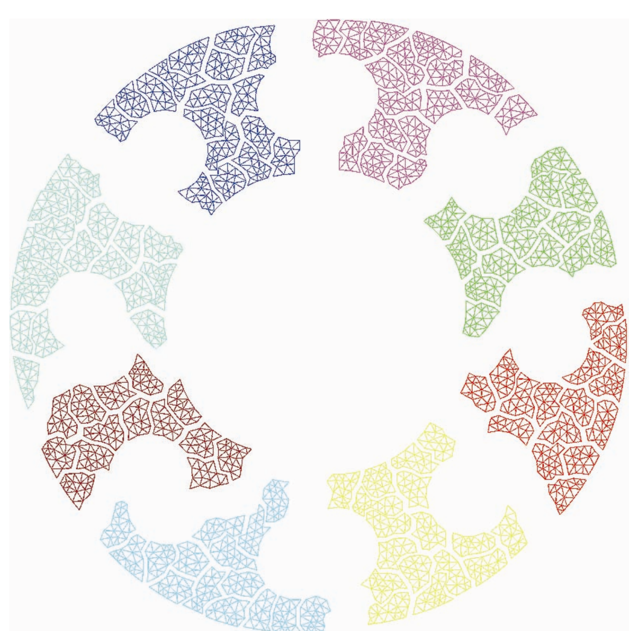
    • Taking advantage of the additional execution contexts may reduce the execution time of the single-node parallel version to make it comparable with the extensively optimized sequential code.

  • Avoid putting too much additional overhead to the programmer.



Intel HT Architecture

2 Multiple Levels of Parallelism



Coarse Grain

• Subdomain level.

• MPI, message-passing implementation across different nodes.

• Superlinear speedup for few processors, almost linear speedup up to 128 processors.

• Use of processes (kernel-level threads provided by the operating system).

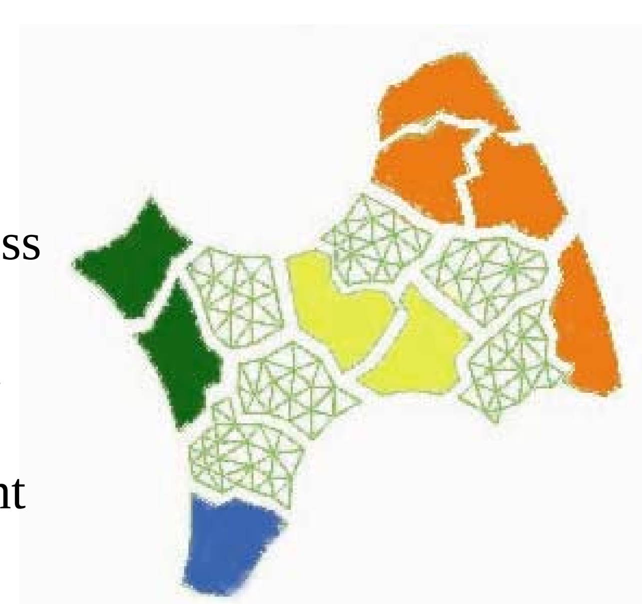
Medium Grain

• Cavity level

• Shared-memory implementation, across the processors of an SMP.

• Requires algorithmic modifications in order to ensure that the computation in one cavity does not affect the concurrent computation of another cavity.

• Future work . . .



Fine Grain

• Element (triangle) level.

• Shared memory implementation, across the multiple execution contexts present in a HyperThreaded processor.

• Too fine-grained parallelism.

• Profiling Data (for a typical problem size) :

  • Element-level code is accountable for **58%** of the total execution time.

  • However:

    • **22 10^6** invocations of the parallelizable function.

    • Only **4-6 usec** computation per invocation.

    • Only **5-6 elements** in average per invocation.

  • Cost of thread triggering is **1 usec** on the specific architecture …

  • Maximum expected speedup is **1.33** to **1.5** without taking into account any additional overheads …

3 Implementation Approaches

Overhead Minimization

• Minimization of the interaction between threads.

  • Use of decentralized application data structures.

  • Use of local, per-thread work queues.

• Use of non-blocking, wait-free synchronization algorithms wherever possible.

• Interesting tradeoff between synchronization and extra work:

  • It is possible to significantly reduce synchronization between threads by bearing the possibility of unnecessary repetition of the computation for the same element by two different threads.

Use of a Threading Substrate (Factory)

• Factory:

  • Facilitates the exploitation of parallelism in C++ programs. Flexible multi-translation of one abstraction of application-level parallelism.

  • User-level threads substrate. Multilevel task parallelism.

  • Strongly typed C++ API.

  • Computation is expressed as "WorkUnits". 1 WorkUnit / element.

  • Custom slab allocator implementation for effective memory management.

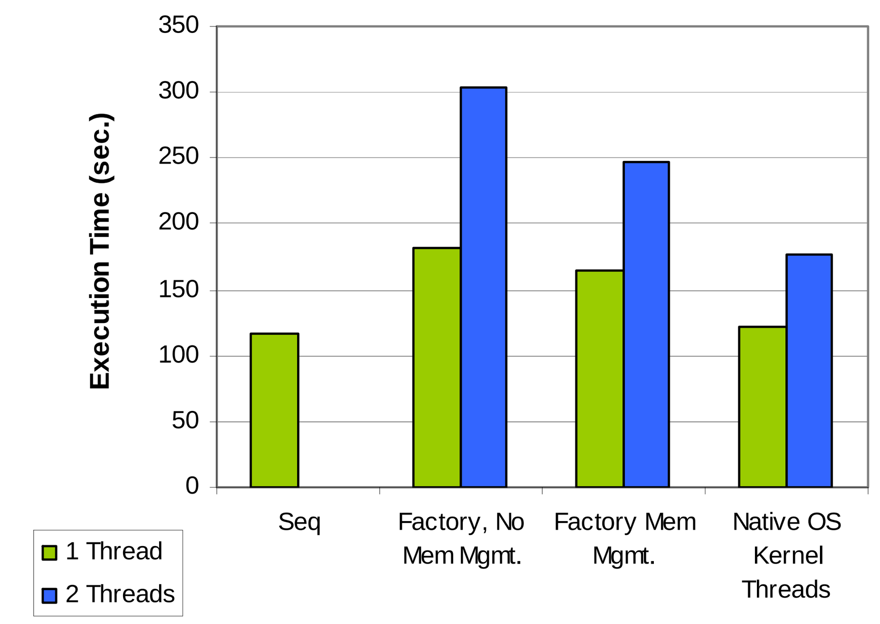
• Overhead for WorkUnit creation, dispatching, destruction : **1 usec.**

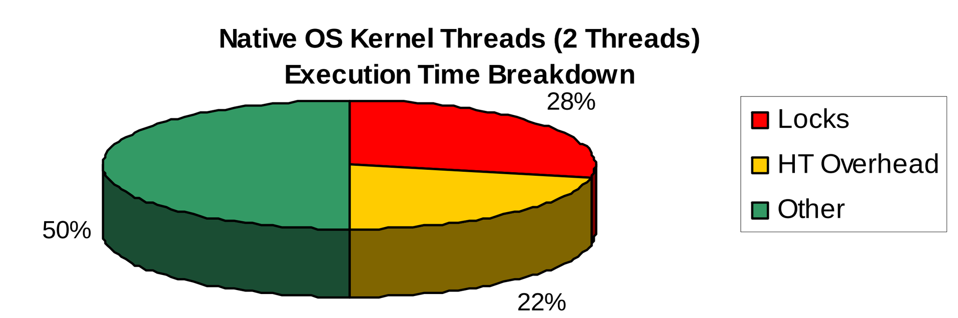
Kernel Threads as Execution Vehicles

• Native, OS kernel threads are used as execution vehicles throughout application life.

• Kernel threads create/enqueue or dequeue/execute work.

4 Prelim. Experimental Evaluation





5 Future Work

• Use simulation to find-out whether the fine-grained parallelism of PCDT is exploitable by architectures that offer H/W support for multithreading

• Target other existing and emerging SMT architectures (IBM Power5, IBM BlueGene, future Intel & AMD multicore processors).

• 3D parallel mesh generation:

  • Coarser-grained parallelism.

  • Higher computational intensiveness.

  • Significant importance real-world application.

6 Acknowledgements

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7 References

[1] **Parallel Delaunay mesh generation kernel**. N. Chrisochoides and D. Nave. Int. J. Numer. Meth. Engng., 58:161–176, 2003.

[2] **Triangle: Engineering a 2D Quality Mesh Generator and Delaunay Triangulator.** J.R. Shewchuk. Proc. 1st Workshop on Applied Computational Geometry, 1996.