

CMSC 714

Lecture 18

Cache Tools

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Notes

- Midterm exam Tuesday, Nov. 13
 - on readings through today
- Group Project interim report due Nov. 20
- OpenMP project grades out soon

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Data and Computation Reordering

- Goal is to improve performance of *irregular* applications
 - ones with data access patterns not known until runtime
 - includes solving PDEs on unstructured or adaptive grids, n-body problems, etc.
 - in this paper, model the access pattern with an *interaction list* that specifies the data elements to access
- Runtime methods to do the same types of optimizations as are done for regular applications
 - ones where data access patterns (often to multi-dimensional arrays) are known at compile-time
 - e.g., loop blocking, interchange, data prefetching
- Methods to reorder data dynamically to improve memory hierarchy behavior
 - improve spatial locality
- Methods to reorder loop iterations
 - typically to improve spatial and temporal locality

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Data and Computation Reordering

- Data reordering – reorder the data elements pointed to by the interaction list (since order really doesn't matter for getting the right answers) – to improve spatial locality
 - first touch method
 - first do a linear scan to determine order elements are accessed, then sort in that order, updating the interaction list to point to the relocated elements
 - space filling curve method
 - use element coordinate information to build a space filling curve that goes through all the elements, which preserves locality in multiple dimensions
 - sort elements according to position on the curve
- Computation reordering – reorder loop iterations, but don't change the locations of the data elements – to improve both spatial and temporal locality
 - space filling curve method
 - use positions of data elements as coordinates for the space filling curve
 - blocking method
 - recursive divide and conquer method to group elements – partition the overall coordinate space, and process elements one partition at a time
- Overall experimental results on 3 applications/kernels show that need to do both computation and data reordering to get best results, and should use space filling curves for both

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MemSpy

- A tool for finding memory performance bottlenecks in serial and parallel programs
 - like MTool, but more detailed view of cache misses
 - and both code- and data-centric views of the causes for cache misses
- Goals are to
 - separately report processor and memory time, to find memory bottlenecks
 - link bottlenecks back to data objects, not just code segments
 - provide memory stats detailed enough to enable programmer to fix bottlenecks
 - why did the cache misses occur?
- High overhead solution
 - use simulation to track cache behavior (no hardware support required)
 - uses Tango simulation/tracing system
 - instrument application via pre-processing, then trace every memory reference with a call to the memory simulator, which then calls MemSpy to compute aggregate statistics on cache events (hits, misses, replacements, etc.)

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MemSpy

- Presents code and data oriented statistics
 - code and data divided into logical units – *code segments* and *data bins*
 - group statistics into each bin
 - code segment is a function/procedure – just need to trace function entry/exit
 - data bin can be a single object, or a group of objects
 - a bin is all memory ranges allocated at same point in source code with identical call paths (same stack)
- Data oriented statistics divided into 3 categories
 - compulsory misses (first use)
 - replacements (capacity misses, conflict misses)
 - invalidations (from cache coherence misses in an SMP)
- Code examples show the utility of data centric view, and breaking down misses into categories
- Performance of instrumented code is very poor, but claim is that it could be improved (never done?)
 - real problem is that multiprocessor execution is simulated by Tango via interleaving processes on a single processor, so does not scale
 - conclusion is that need hardware trace facility on a multiprocessor

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