TaskMan: Simple Task-Parallel Programming in C++

"Let me tell you how it will be..."

Derek Hower & Steve Jackson

University of Wisconsin – Madison

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Executive Summary

- Task-Parallel Programming is gaining steam.
- Existing support in C++ sacrifices programmability for performance
- TaskMan - A task programming interface & runtime
  - Simple interface
  - Feels like serial code
- Results
  - Comparable to existing systems with large tasks
  - Slower with small tasks
    - ...but we haven't yet applied optimizations!

Task Parallel Programming

- Task
  - An *independent* unit of work
  - Typically smaller than a thread
  - Many more tasks than cores
- Tasks executed by runtime
  - Schedules and synchronizes tasks
  - Load balancing
- Examples
  - Loops with no loop-carried dependence
  - Tree traversal algorithms
  - Recursion

Runtime Characteristics

- Tasks Tuple: $< func, arg_1, arg_2, ... >$
  - Stored on a task queue
- Always-present helper threads
- Task Queues
  - Logically global, practically local
  - One per helper thread (i.e. per core)
  - A thread that runs out of local work steals from another queue

Existing Systems

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  - C++ Library from Intel
  - Object-Oriented approach to task programming
  - Task syntax clunky (in our opinion)

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- Thread Parallel Library (TPL, aka ParallelFX)
  - C# library from Microsoft
  - Task syntax similar to TaskMan
  - Proprietary
  - First preview release came out on December 5
    - No, we haven't tried it

TaskMan Example

```
int fib(int n)
{
  if (n < 2)
    return (n);
  else {
    int x, y;
    x = fib( n-1 );
    y = fib( n-2 );
    return (x + y);
  }
}
```

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}
```

```
int fib(int n)
{
  if (n < 2)
    return (n);
  else {
    result<int> x, y;
    x = task( fib, n-1 );
    y = task( fib, n-2 );
    return (*x + *y);
  }
}
```

TaskMan Implementation

`task( ... )`

- Push the task on top of thread's work queue, then continue executing
- Extensive use of templates
  - \+ `task()` can accept any combination of arguments
  - \+ Type safety
  - – Explosively verbose error messages

TaskMan Implementation

`result<...>`

- Represents a *future*
- `operator*` forces the future
  - Pending tasks are evaluated until result is ready
  - Once launched, a task never leaves its thread

\+ Simple approach, no need for continuation passing

− Potentially deep recursions

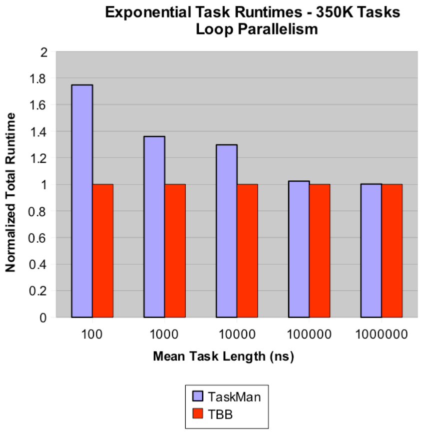
Results

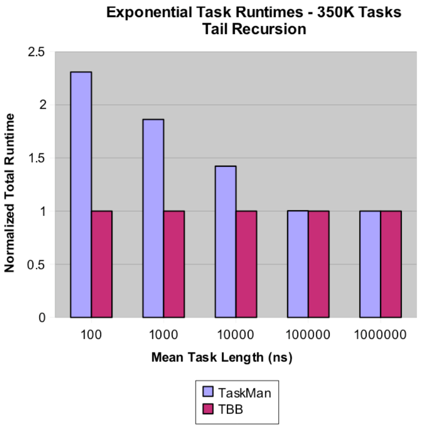
- microbenchmark: `stat`
- Converted Cilk benchmarks: `heat`, `plu`, `matmul`
- Othello AI

Unless otherwise noted, performance numbers are for an 8 core Intel system.

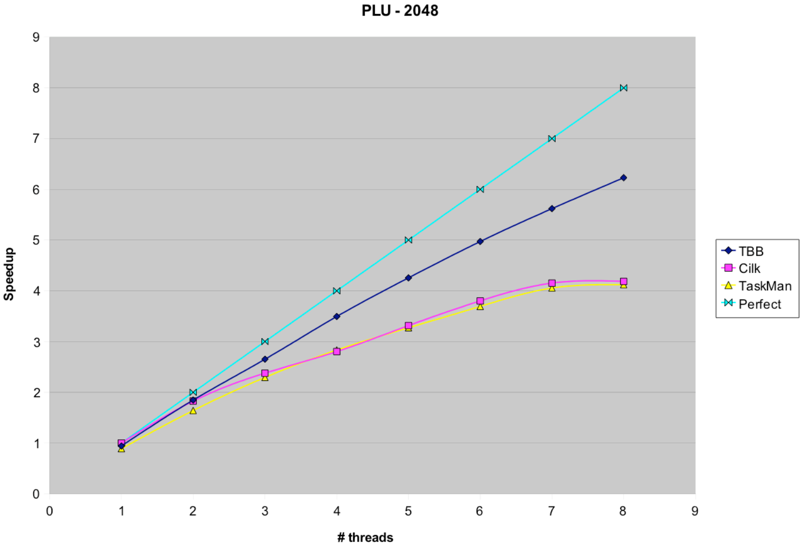
Microbenchmark: Statistically Distributed Task Sizes

Create and run no-op tasks that take time t to complete, where t is produced via a statistical distribution.

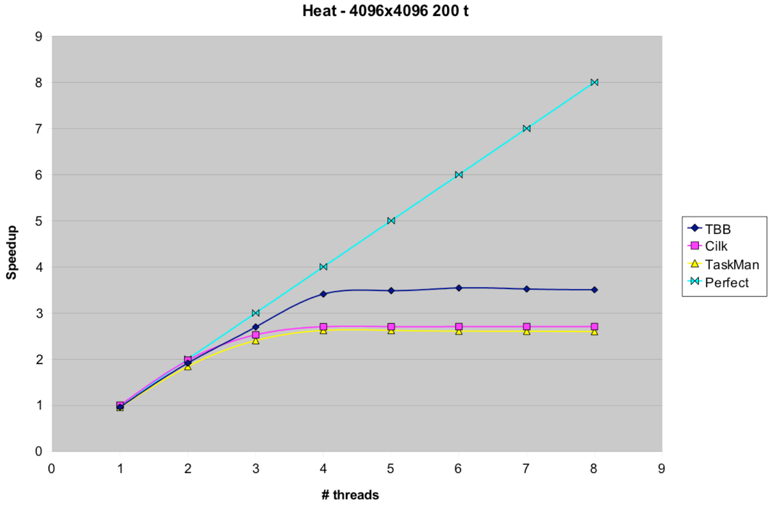




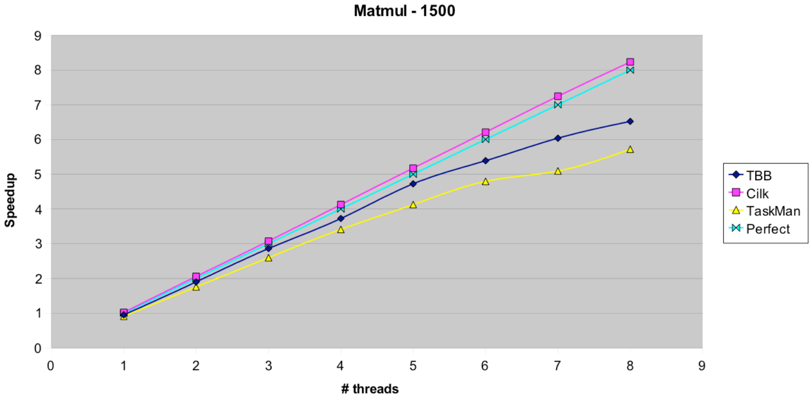
Converted Cilk Benchmark: plu



Converted Cilk Benchmark: heat

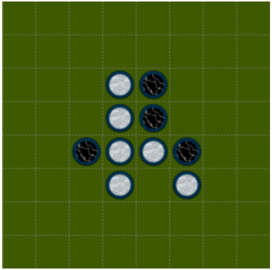


Converted Cilk Benchmark: Matrix Multiply

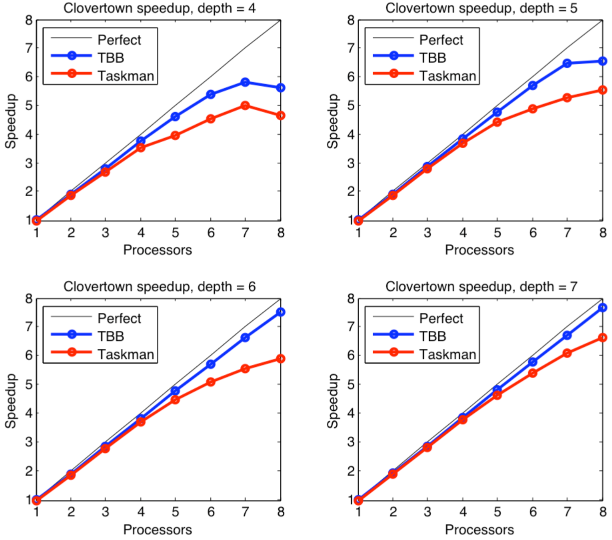


Othello Benchmark

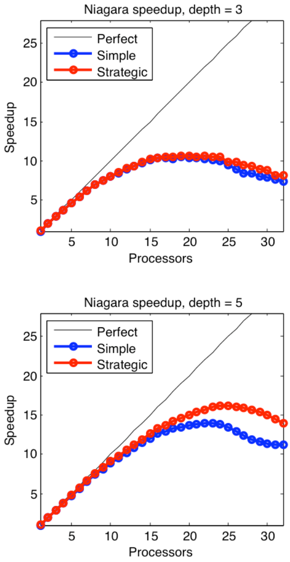
- A recursive minimax AI for the game Othello (Reversi)
- Two different board evaluators:
  - Simple: evaluation function is a count of pieces on the board
    $\longrightarrow$ shorter tasks
  - Strategic: evaluation function considers board position (corners, edges, etc.)
    $\longrightarrow$ longer tasks



Othello vs. TBB



Othello on Niagara: 8 cores x 4 threads = 32 threads



Future Directions

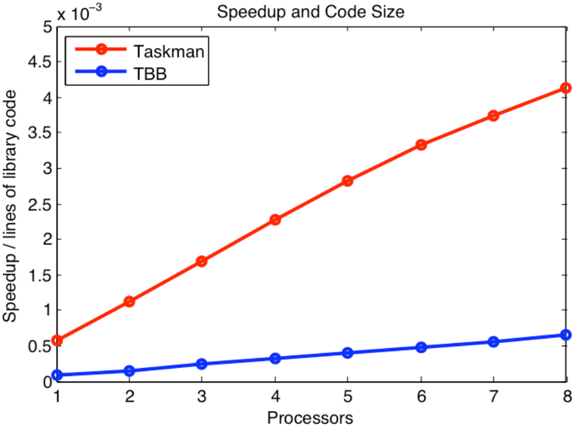
- Optimize TaskMan for performance
- Side-by-side comparison of work queue implementations
  - Lock-free structures?
  - Transactional memory?
  - Dedicated task-management hardware?
- Extend programming model
  - e.g. parallel loops
  - But avoid needlessly complex syntax
  - Compiler may become necessary

Concluding Remarks

- Task parallelism is a useful programming model
  - Much easier to write than raw pthreads code!
  - Particularly well-suited to certain problems
    - (And not for certain others)
- The work-stealing task queue algorithm supports this model
  - A simple, untuned implementation can achieve significant speedup
  - Optimized implementations are still better

Concluding Remarks

But, there is beauty in simplicity:



Backup: Fibonacci in Cilk

```
cilk int fib(int n)
{
  if (n < 2)
    return (n);
  else {
     int x, y;
     x = spawn fib(n - 1);
     y = spawn fib(n - 2);
     sync;
     return (x + y);
  }
}
```

Backup: Fibonacci in TBB

```
class FibTask: public task {
public:
  int* const sum;
  const int n;

  FibTask( long _n, long* _sum ) :  sum(_sum), n(_n) {}

  task* execute(){
      int x, y;
      FibTask& a = *new( allocate_child() ) FibTask(n-1, &x);
      FibTask& b = *new( allocate_child() ) FibTask(n-2, &y);
      set_ref_count(3);
      spawn(b);
      spawn_and_wait_for_all(a);
      *sum = x+y;
    }
    return NULL;
  }
};
```