Task Parallelism

- Divide-and-conquer
  - Each *task* recursively creates n tasks that divide the problem into subproblems
  - Each task t then waits for all n tasks to finish and then may 'combine' the responses
  - At some point the recursion stops (at the bottom of the tree), and some sequential kernel is executed
  - Then the result is propagated upward in the tree recursively
  - Examples: fibonacci, quick sort, ...

Task Parallelism

- State-space search
  - Each *task* recursively creates n tasks to partition the search space
  - If the problem is one-solution search, as soon as a task encounters a solution, the program may need to terminate
    - Kill-chasing problem
- All-solution search may require behaviour much like divide-and-conquer where values are combined
  - Example: all-solution nqueens
  - Number of solutions are accumulated recursively up the tree

Fibonacci Example

- Each `Fib` chare is a task that performs one of two actions:
  - Creates two new `Fib` chares to compute $fib(n-1)$ and $fib(n-2)$ and then waits for the response, adding up the two responses when they arrive
    - After both arrive, sends a response message with the result to the parent task
    - Or prints the value and calls `CkExit()` if it is the root
  - If $n = 1$ or $n = 0$ (passed down from the parent) it sends a response message with n back to the parent task

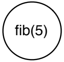
Fibonacci Example

```
mainmodule fib {
  mainchare Main {
    entry Main(CkArgMsg* m);
  };

  chare Fib {
    entry Fib(int n, bool isRoot, CProxy_Fib parent);
    entry void response(int value);
  };
};
```

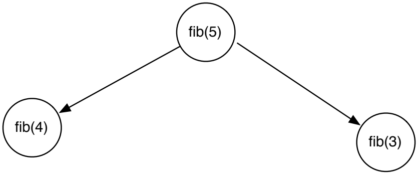
Fibonacci Example

```
struct Main : public CBase_Main {
  Main(CkArgMsg* m) {
    CProxy_Fib::ckNew(atoi(m->argv[1]), true, CProxy_Fib());
  }
};

struct Fib : public CBase_Fib {
  CProxy_Fib parent; bool isRoot; int result, count;

  Fib(int n, bool isRoot_, CProxy_Fib parent_)
    : parent(parent_), isRoot(isRoot_), result(0), count(n < 2 ? 1 : 2) {

    if (n < 2) response(n);
    else {
      CProxy_Fib::ckNew(n - 1, false, thisProxy);
      CProxy_Fib::ckNew(n - 2, false, thisProxy);
    }
  }

  void response(int val) {
    result += val;
    if (--count == 0) {
      if (isRoot) {
        CkPrintf("Fibonacci number is: %d\n", result);
        CkExit();
      } else {
        parent.response(result);
        delete this;
      }
    }
  }
};
```

Fibonacci Execution



Fibonacci Execution



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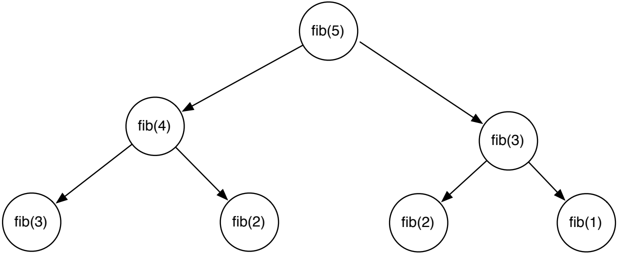

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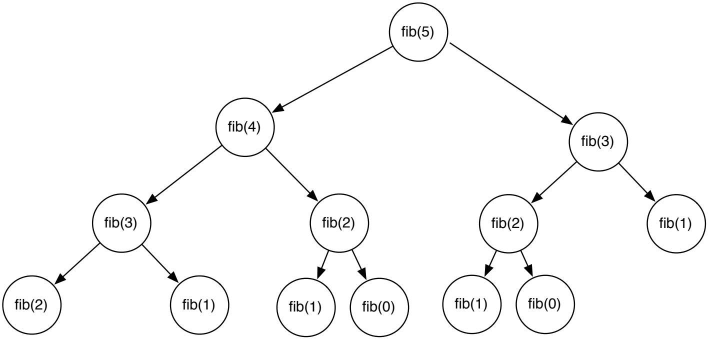
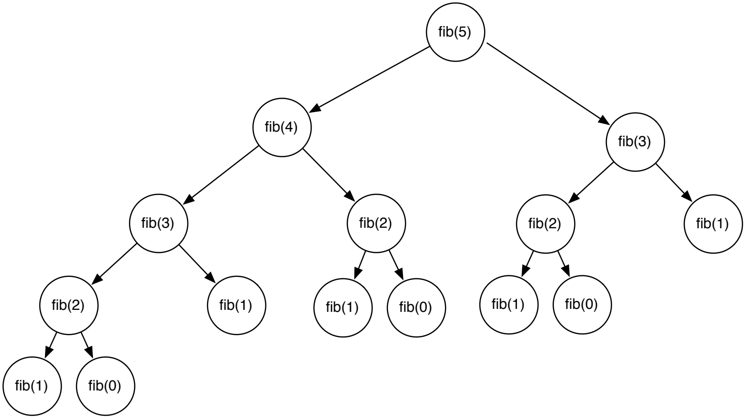
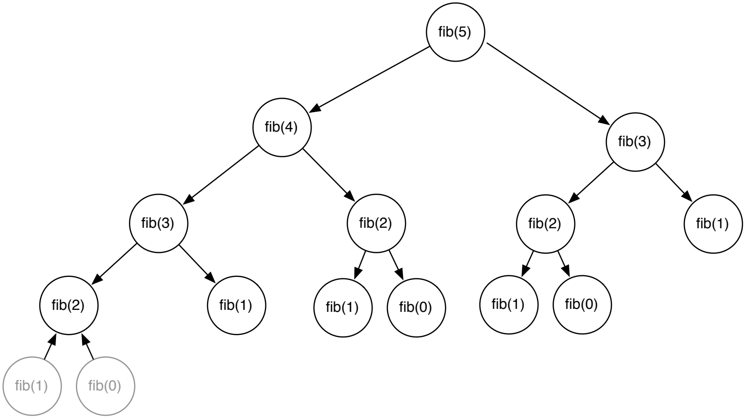


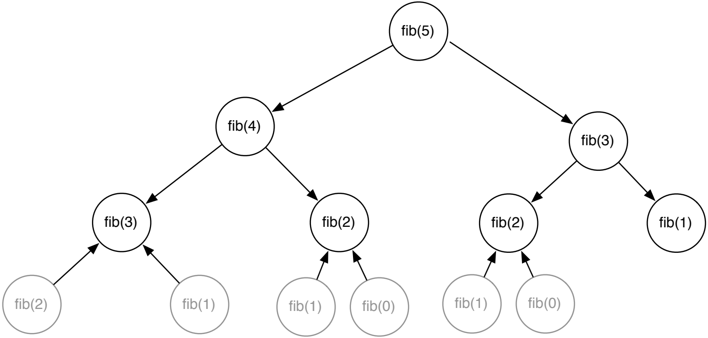
Fibonacci Execution



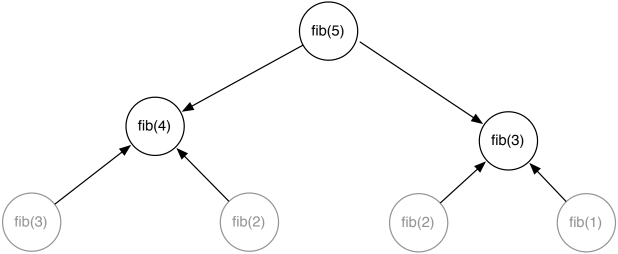
Fibonacci Execution



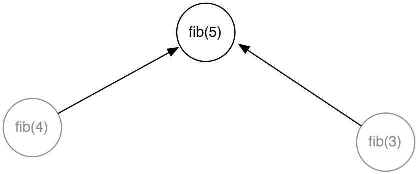
Fibonacci Execution



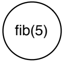
Fibonacci Execution



Fibonacci Execution



Fibonacci Execution

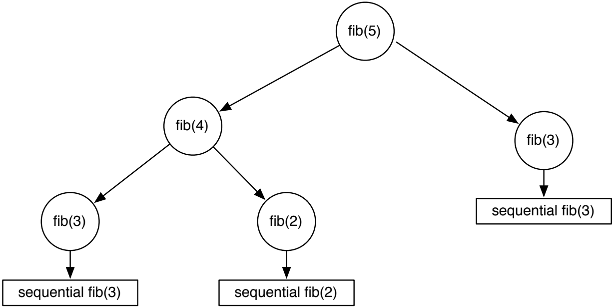


Fibonacci Performance

- How much work/computation does each chare do in this example?
- What are some of the overheads of this approach?
- Is there way we can reduce/amortize the overhead?

Possible Solution

- Set a sequential threshold in the computational tree
  - Past this threshold (i.e. when $n < threshold$), instead of constructing two new chares, compute the fibonacci sequentially



- $fib(5), fib(4)$ are fine grains, $fib(3), fib(2)$ are coarser grains
- The coarser grains now amortize the cost of the fine-grained execution

Fibonacci w/Threshold Example

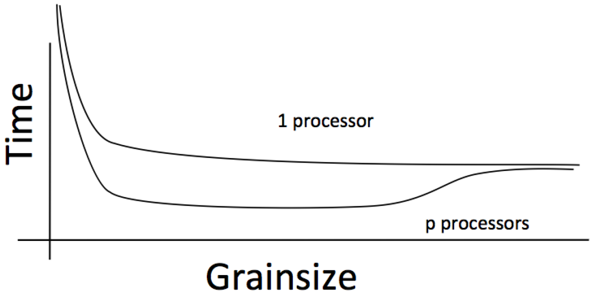
```
#define THRESHOLD 10

struct Main : public CBase_Main { /* ... same as before ... */ };

struct Fib : public CBase_Fib {
  CProxy_Fib parent; bool isRoot; int result, count;

  Fib(int n, bool isRoot_, CProxy_Fib parent_)
    : parent(parent_), isRoot(isRoot_), result(0), count(n < THRESHOLD ? 1 : 2) {

    if (n < THRESHOLD) response(seqFib(n));
    else {
      CProxy_Fib::ckNew(n - 1, false, thisProxy);
      CProxy_Fib::ckNew(n - 2, false, thisProxy);
    }
  }

  int seqFib(int n) { return (n < 2) ? n : seqFib(n - 1) + seqFib(n - 2); }

  void response(int val) {
    result += val;
    if (--count == 0) {
      if (isRoot) {
        CkPrintf("Fibonacci number is: %d\n", result);
        CkExit();
      } else {
        parent.response(result);
        delete this;
      }
    }
  }
};
```

Amdahlss Law and Grainsize

- Original "law":
  - If a program has $K\%$ sequential section, then speedup is limited to $\frac{100}{K}$.
    - If the rest of the program is parallelized completely
- Grainsize corollary:
  - If any individual piece of work is $> K$ time units, and the sequential program takes T_{seq},
    - Speedup is limited to $\frac{T_{seq}}{K}$
- So:
  - Examine performance data via histograms to find the sizes of remappable work units
  - If some are too big, change the decomposition method to make smaller units

Grainsize

- (working) Definition: the amount of computation per potentially parallel event (task creation, enqueue/dequeue, messaging, locking. .)



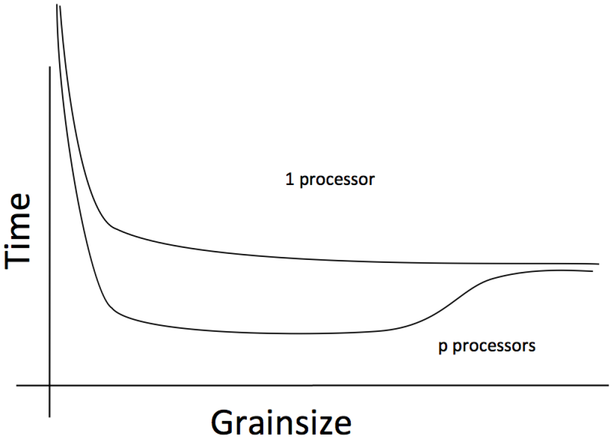
Grainsize and Overhead

- What is the ideal grainsize?
- Should it depend on the number of processors?

$$T_1 = T\left(1 + \frac{v}{g}\right)$$
$$T_p = max\left\{g, \frac{T_1}{p}\right\}$$
$$T_p = max\left\{g, \frac{T\left(1+\frac{v}{g}\right)}{p}\right\}$$

v: overhead per message,
T_p: p processor completion time
g: grainsize (computation per message)

Grainsize and Scalability



Rules of thumb for grainsize

- Make it as small as possible, as long as it amortizes the overhead
- More specifically, ensure:
  - *Average* grainsize is greater than kv (say $10v$)
  - No single grain should be allowed to be too large
    - Must be smaller than $\frac{T}{p}$, but actually we can express it as:
    - Must be smaller than kmv (say $100v$)
- Important corollary:
  - You can be at close to optimal grainsize without having to think about p, the number of processors

How to determine/ensure grainsize

- Compiler techniques can help, but only in some cases
  - Note that they don't need precise determination of grainsize, just one that will satisfy a broad inequality
    - $kv < g < mkv$ $(10v < g < 100v)$