# Using Threads for Parallelism

CS 475

## Introduction

- Goal: connecting multiple computers to get higher performance
  - Multiprocessors
  - Scalability, availability, power efficiency
- Job-level (process-level) parallelism
  - High throughput for independent jobs
- Parallel processing program
  - Single program run on multiple processors
- Multicore microprocessors
  - Chips with multiple processors (cores)

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## Hardware and Software

- Hardware
  - Serial: e.g., Pentium 4
  - Parallel: e.g., quad-core Xeon e5345
- Software
  - Sequential: previous classes
  - Concurrent: this class
- Sequential/concurrent software can run on serial/parallel hardware
  - Challenge: making effective use of parallel hardware

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## Parallel Programming

- Parallel software is the problem
- Need to get significant performance improvement
  - Otherwise, just use a faster uniprocessor, since it's easier!
- Difficulties
  - Partitioning
  - Coordination
  - Communications overhead

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## Amdahl's Law

- Sequential part can limit speedup
- Example: 100 processors, 90× speedup?
  - $T_{new} = T_{parallelizable}/100 + T_{sequential}$
  - $$\text{Speedup} = \frac{1}{(1-F_{parallelizable}) + F_{parallelizable}/100} = 90$$
  - Solving: $F_{parallelizable} = 0.999$
- Need sequential part to be 0.1% of original time

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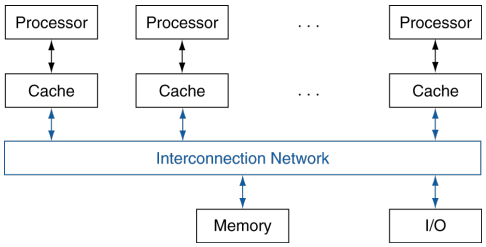
## Shared Memory

- SMP: shared memory multiprocessor
  - Hardware provides single physical address space for all processors
  - Synchronize shared variables using locks
  - Memory access time
    - UMA (uniform) vs. NUMA (nonuniform)

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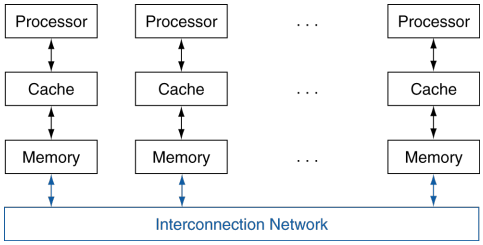
## Message Passing

- Each processor has private physical address space
- Hardware sends/receives messages between processors

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## Loosely Coupled Clusters

- Network of independent computers
  - Each has private memory and OS
  - Connected using I/O system
    - E.g., Ethernet/switch, Internet
- Suitable for applications with independent tasks
  - Web servers, databases, simulations, …
- High availability, scalable, affordable
- Problems
  - Administration cost (prefer virtual machines)
  - Low interconnect bandwidth
    - c.f. processor/memory bandwidth on an SMP

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## Grid Computing

- Separate computers interconnected by long-haul networks
  - E.g., Internet connections
  - Work units farmed out, results sent back
- Can make use of idle time on PCs
  - E.g., SETI@home, World Community Grid

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## Using threads for parallelism

- Shared memory multiprocessors, multicores
- Two common approaches
  - Partition "work" into t portions and then assign each of t different threads to work on its own region
  - "Bag of tasks" approach
    - When partitioning work equally among threads in advance is difficult

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## Example: Parallel Sum

```
void *sum(void *vargp);

long psum[MAXTHREADS];

long nelems_per_thread; /* Number of elements summed by each thread */

int main(int argc, char **argv) {
        long i, nelems, log_nelems, nthreads, result = 0;
        pthread_t tid[MAXTHREADS];
        int myid[MAXTHREADS];

        if (argc != 3) {
                printf("Usage: %s <nthreads> <log_nelems>\n", argv[0]);
                exit(0);
        }
        nthreads = atoi(argv[1]);
        log_nelems = atoi(argv[2]);
        nelems = (1L << log_nelems);

        if  ((nelems % nthreads) != 0 || (log_nelems > 31)) {
                printf("Error: invalid nelems\n");
                exit(0);
        }
}
```

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## Parallel Sum cont'd

```
        nelems_per_thread = nelems / nthreads;

        for (i = 0; i < nthreads; i++) {
                myid[i] = i;
                Pthread_create(&tid[i], NULL, sum, &myid[i]);
        }
        for (i = 0; i < nthreads; i++)
                Pthread_join(tid[i], NULL);
        }

        for (i = 0; i < nthreads; i++)
                result += psum[i];

        if (result != (nelems * (nelems-1))/2)
                printf("Error: result=%ld\n", result);
                exit(0);
        }
```

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## Parallel Sum cont'd

```
void *sum(void *vargp) {

    int myid = *((int *)vargp);                    /* Extract the thread ID
    */

    long start = myid * nelems_per_thread;     /* Start element index */
    long end = start + nelems_per_thread;       /* End element index */
    long i, sum = 0;

    for (i = start; i < end; i++) {
          sum += i;
    }
    psum[myid] = sum;
    return NULL;
}
```

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## Bag of Tasks approach

- Coordinator thread maintains a work queue or data structure from which worker threads remove tasks
- Easier to implement ***load balancing*** when amount of computation associated with task is hard to estimate in advance

```
while (true) {
     get a task from the bag;
     if (no more tasks)
          break;                    # exit the while loop
     execute the task, possibly generating new ones;
}
```

Outline of worker processes using the bag-of-tasks paradigm.

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