Shared Memory
&
OpenMP

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-
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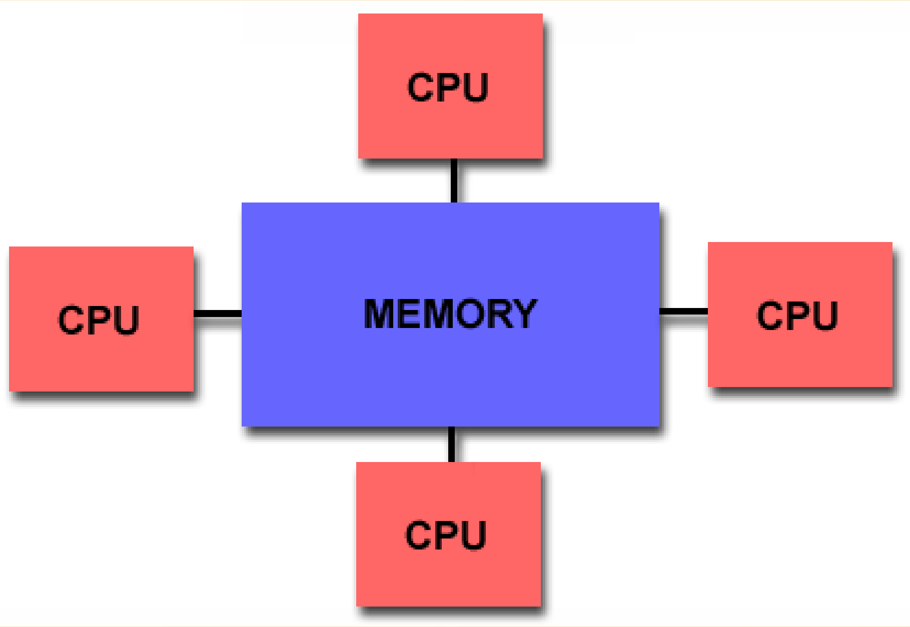
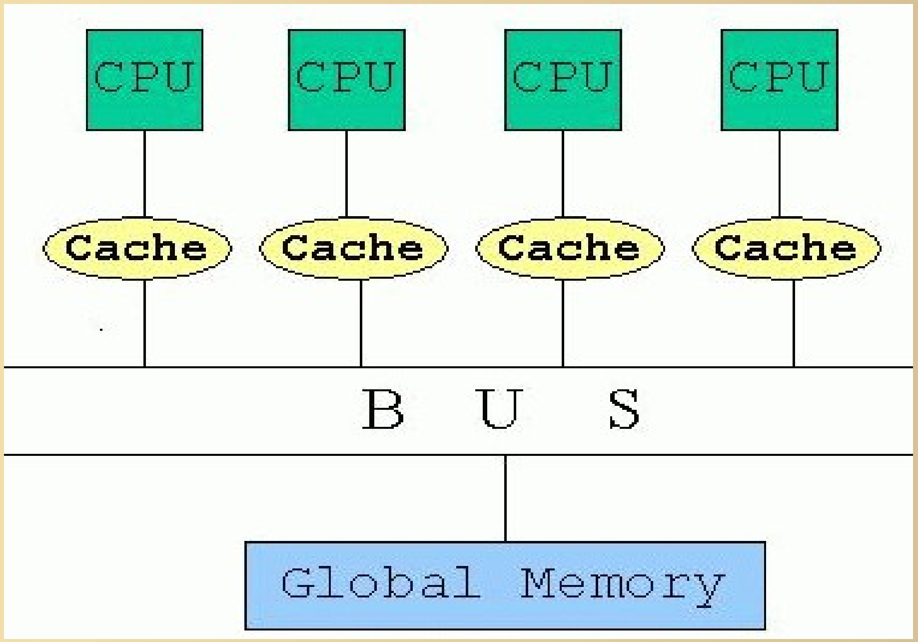
Shared Memory Architecture





Threads

- Short for
  “Thread of execution”
- Threads execute the statements within a program.
- Threads are usually created by a process

Distributed:

- Multiple Instances of program created
- Each process has it's own local memory
- One process cannot see anything local to another process
- May not even be on same node
- Memory communicated via message passing

Shared

- Only one instance runs
- Threads are created as needed within
- Each thread has local memory
- Each thread can be run by separate CPUs

  or
- Each thread can run on the same CPU
- Local memory can be communicated by updates to main memory

The Round Table

- Round table with one worker

  worker has:

  -Pencil

  -paper

  -calculator

  -public checkbook to balance

The Round Table

- Worker calls in 2 more helpers.
- The helpers get:

  -pencil

  -paper

  -calculator

Helpers may also look at the public checkbook!

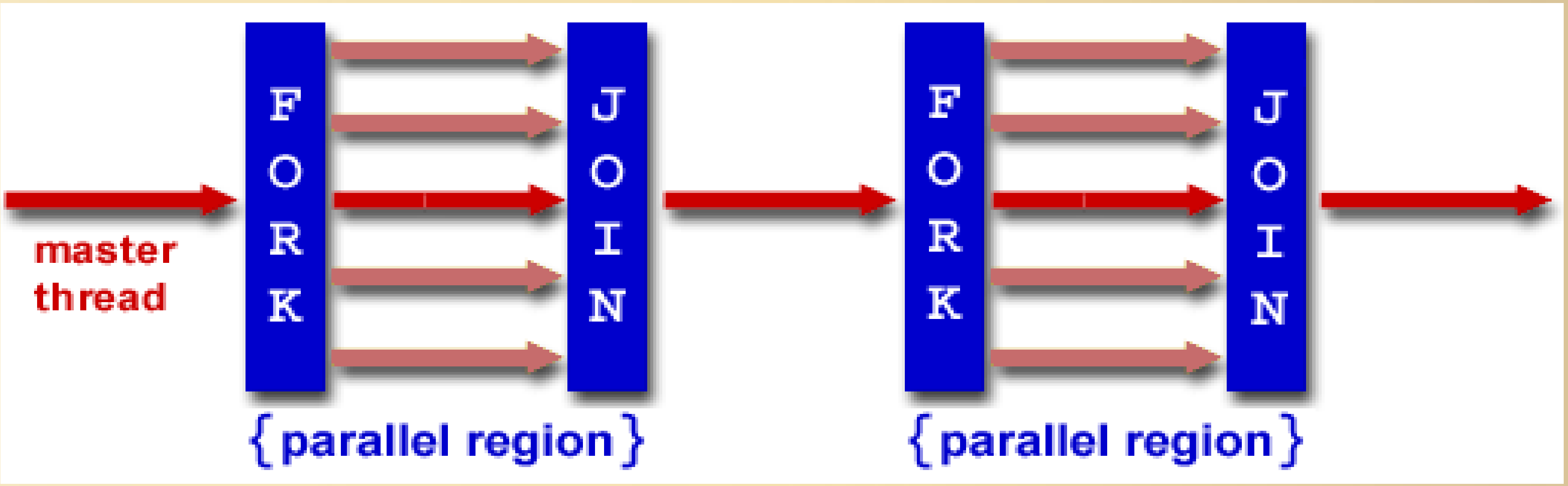
The Round Table

- No one can see what you write on your own paper.
- But you can change the public checkbook at any time so everyone can see.

The Round Table

- Helpers finish their jobs, and then are dismissed.
- Before leaving they record their results in the public checkbook.

Fork and Join



Notice the areas with just the original master thread.

Amdahl's Law

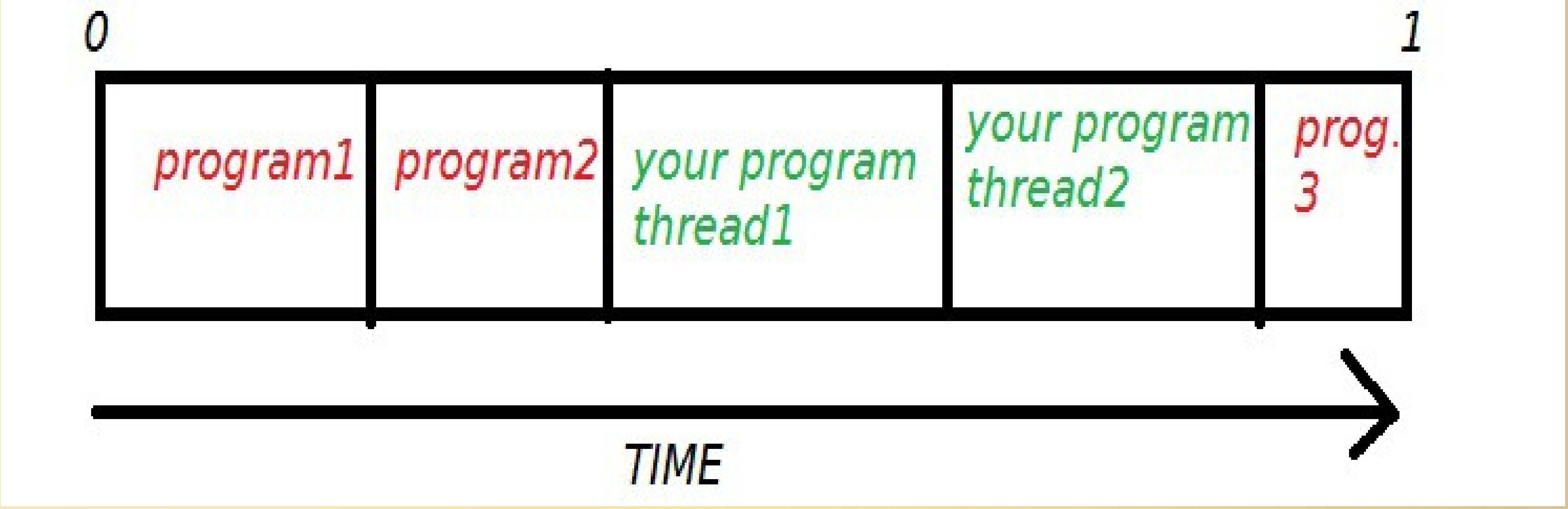
$$SpeedUp = \frac{1}{(1-F)+\frac{F}{N}}$$

- F= the parallelizable sections of serial code
- N = number of processors

Pseudo Parallelism?

- What if you have two threads on one processor?
- What about your operating system?

Time Slices



- A processor can only do one thing at a time.
- So it switches between jobs quickly

Caveats

The word we hear so much:

Overhead

- Creating threads
- Communicating between threads
- Managing Memory Access

Thread Creation Overhead

- Anything else running?
- Resources present?
- Are there enough physical processors?
- These can be expensive
- Expense rises as the number of threads required rises
- No work until workers arrive

Thread Communication Overhead

- Do they need to talk?
- Structure scenarios for communicating
- Choosing reliable communications

- Remember time spent talking is not time spent working

Shared Memory Concerns

- Shared literally means “Shared”

  A:What's mine is mine, I do what I please

  B:What's yours is mine, I do what I please

Managing Memory Access

- Writing at the same time
- Only reading valid data
- Waiting..... waiting..... waiting....

OpenMP

- Don't confuse with OpenMPI
- MP means “multiprocessing”

- Unlike MPI, some OpenMP capabilities require compiler support, and aren't linked into your executable.

Compiling OpenMP Programs

- Call your openmp compliant compiler as normal.

  Example:

  gcc filename.c

- Add your appropriate compiler flag to enable openMP.

  GNU = -fopenmp ; Intel = -Qopenmp ; etc.

  check → openmp.org/wp/openmp-compilers/

  - Gcc -g -o myprogram -fopenmp filename.c -lm

Going Parallel

- #include <stdio.h>
-
- using namespace std;
- const int thread_count = 2;
-
- void Hello(void)
- {
- printf(“Oh well hellloooooooo!\n”);
- }
- int main(void)
- {
- # pragma omp parallel num_threads(thread_count)
- Hello();
- return 0;
- }
-

Setting the number of threads

- export OMP_NUM_THREADS = #
- setenv OMP_NUM_THREADS #

- # pragma omp parallel num_threads(thread_count)

changes the number of threads arbitrarily

The Parallel Construct - C

- # pragma omp parallel
  - Next structured block runs in parallel

    the number of threads used are determined by OMP_NUM_THREADS

    or

    THE NUMBER OF AVAILABLE PROCESSORS
  - OMP_NUM_PROCS

- Clauses can be added to refine your approach

Parallel clauses

- num_threads(int)
  - Use: #pragma omp parallel num_threads(15) specifies the number of threads to run in block

- private(variablename1, variablename2,...,)
  - Use: #pragma omp parallel private(i, my_rank) grants all threads in block a local version of the specified variables, that they can manipulate

Parallel for construct

- |-----|-----|-----|-----|-----|-----|-----|-----|
- # pragma omp parallel for

```
for(int i=0; i<limit; i++){sum+=i;}
```

- Assuming that sum was defined before
  - Sum is visible and shared to all threads
  - No while loops or do while loops

Parallel for Construct

- Trouble comes at the statement:
  - sum+=i;

  because the variable is shared.

- Who will update the variable and when?

Critical Sections

- You don't want multiple updates
- Make the area mutually exclusive

We could use:

```
# pragma omp critical
    {sum+=i;}
```

Critical Sections

- Bonus:
  - No need to worry about interrupts
- Caveats:
  - This area is SERIAL BY NATURE
  - Performance hit

Parallel for Construct

- We could make the variable private
  - # pragma omp parallel for private(sum)

- Now its up to us to gather the values from each thread
- This is a lot of work.

The Reduction Clause

```
Int sum = 0, limit = 10000000;
# pragma omp parallel for num_threads(8)  \
    reduction(+: sum)
    for(int i=0; i<limit; i++){sum += i;}
```

- sum+=i remains parallel
- I no longer have to coordinate a reduction manually

Runtime Libraries

- #include <omp.h>

- Who am I, How many of us are there?

  Int omp_get_num_threads();

  int omp_get_thread_num();

```
#include <cstdio>
#include <omp.h>
main () {

int nthreads, tid;

/* Fork a team of threads with each thread having a private tid
variable */

#pragma omp parallel private(tid)
{


/* Obtain and print thread id */

tid = omp_get_thread_num();

printf("Hello World from thread = %d\n", tid);
printf("Hello, I may appear in what seems a random spot!\n");

/* Only master thread does this */

if (tid == 0)

{

nthreads = omp_get_num_threads();

printf("Number of threads = %d\n", nthreads);

}

} /* All threads join master thread and terminate */

return 0;
}
```

OpenMP – Area Under the curve

- Setup OpenMP (-fopenmp, setenv)
- Defining your constants
- Determining your number of rectangles
- Fork a team to create chunks of rectangles
- Calculate areas
- Remember to use reduction on for construct
- Output result and timing