A Brief Introduction to Parallel Computing

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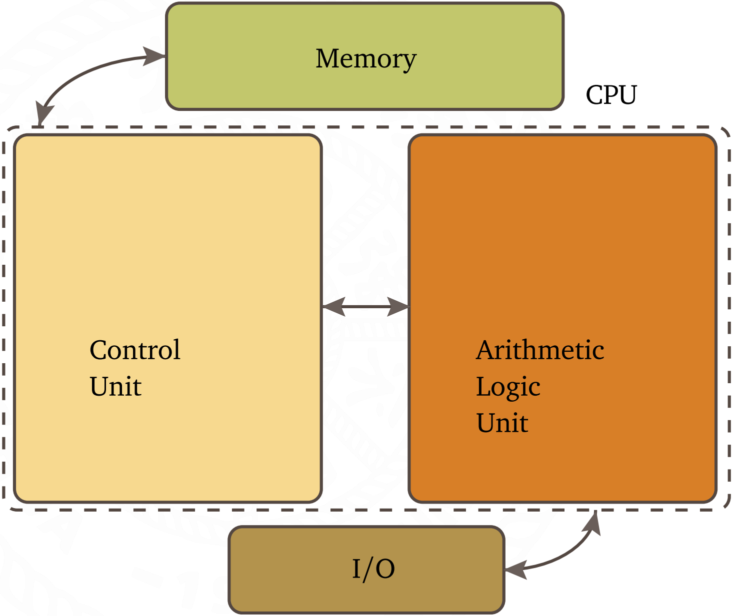
Prologue

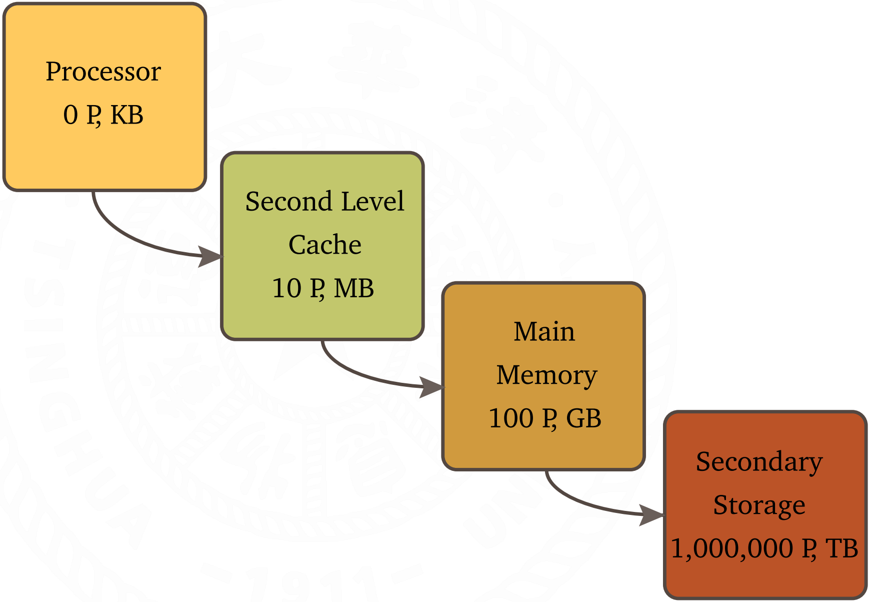
Why Parallel Computing?

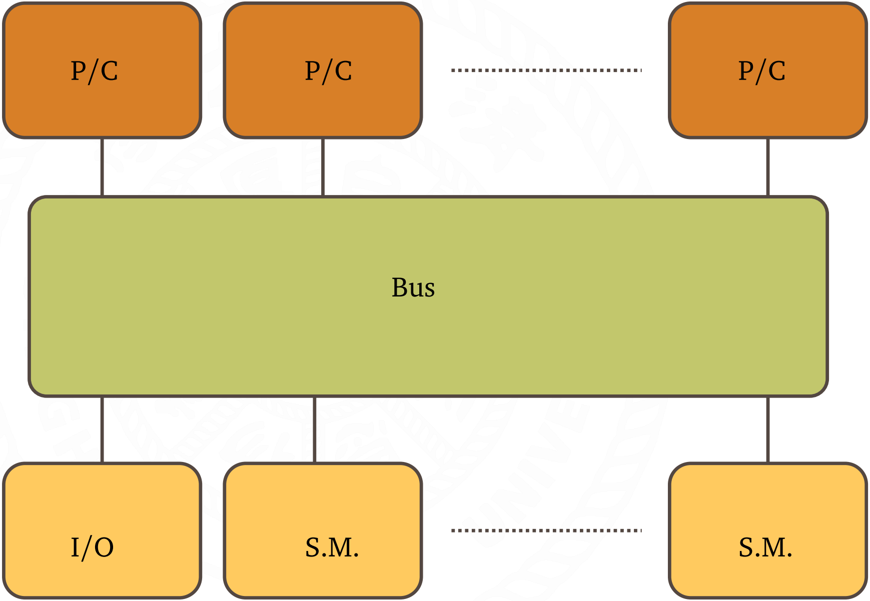
Quick Review

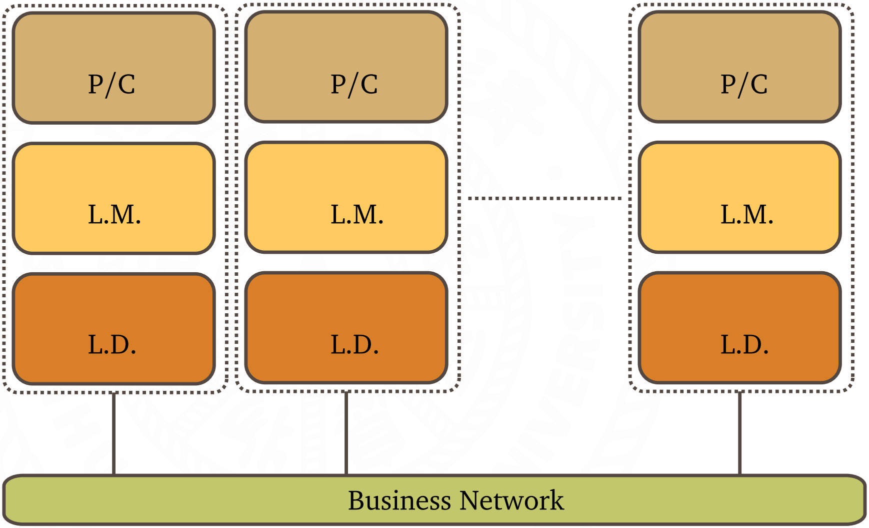
Introduction to Hardware


Memory
CPU
Control Unit
Arithmetic Logic Unit
I/O

Device	Pro.	Sec. Lev. Cac.	Main Mem.	Sec. Sto.
CPU Period	0	10	100	1,000,000
Speed	10GB/s	2GB/s	1GB/s	10MB/s
Size	KB	MB	GB	TB


Processor
0 P, KB
Second Level
Cache
10 P, MB
Main
Memory
100 P, GB
Secondary
Storage
1,000,000 P, TB


P/C
P/C
P/C
Bus
I/O
S.M.
S.M.


P/C
P/C
P/C
L.M.
L.M.
L.M.
L.D.
L.D.
L.D.
Business Network

Before we hit the road,

Processes vs. Threads

Processes

Resource Holder
Independent Execution
Programs Loaded as Processes by OS

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Threads

(Master) Thread at Program Entry Point
More Threads Created by Existing Ones Possible
Separate Stack for each thread
Shared Code and Data Segments

Why Threads?

- Efficient Data Sharing

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- Efficient Data Sharing
- High Multi-core Performance

Typical Parallel Models I.

Shared Memory Model

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- Unified Address Space

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- Able to Explicitly Synchronize
- Local Variables along with Shared Variables
- Threads Created and Destroyed Dynamically

A Typical Terrible Example

```
static int s=0;
```

Thread 1

```
reg0=f(A[i]);
reg1=s;
reg1=reg1+reg0;
s=reg1;
```

Thread 2

```
reg0=f(A[i]);
reg1=s;
reg1=reg1+reg0;
s=reg1;
```

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Thread 2

```
reg0=f(A[i]);
reg1=s;
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```

Wait a moment

What value will “s” take?

Eureka!

Here is the problem! There are more than one threads visiting the variable "s" at the same moment.

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Remember

This is very important!

A Typical Good Example

static int s=0;
static lock lk;

Thread 1

```
local_s1=0;
for i=0, n/2-1
    local_s1=local_s1+f(A[i]);
lock(lk);
s=s+local_s1;
unlock(lk);
```

Thread 2

```
local_s2=0;
for i=0, n/2-1
    local_s2=local_s2+f(A[i]);
lock(lk);
s=s+local_s2;
unlock(lk);
```

OpenMP

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Tips

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Supported by:

- C/C++/Fortran
- Sun Compiler/GNU Compiler/Intel Compiler

Typical Parallel Models II.

Message Passing Model

Argonne
NATIONAL LABORATORY

Message Passing Model

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- Explicit Send/Receive Pair
- Explicitly Synchronize as Default
- Process Number Decided Before Launch

Message passing involves message sending and receiving.

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- Blocking, e.g. **Telephone**

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- Blocking, e.g. **Telephone**
- Non-blocking, e.g. **Post Office**

Emm,

Feel the difference?

A Typical Terrible Example

Process 1

```
xlocal=A[1];
send xlocal, proc2;
receive xremote, proc2;
s=xlocal+xremote
```

Process 2

```
xlocal=A[2];
send xlocal, proc1;
receive xremote, proc1;
s=xlocal+xremote
```

A Typical Terrible Example

Process 1

xlocal=A[1];
send xlocal, proc2;
receive xremote, proc2;
s=xlocal+xremote

Process 2

xlocal=A[2];
send xlocal, proc1;
receive xremote, proc1;
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Wait a moment

Will there be an interlocking?

Eureka!

Send & Receive are blocking operation. The sender will wait silently until the message is received by a receiver.

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Of course, we may also implement this in a non-blocking way...

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Process 2

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receive xremote, proc1;
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Of course, we may also implement this in a non-blocking way...

However, non-blocking is not always reliable.

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Supporting:

- C/C++/Fortran

Want to know more?

More About OpenMP

Obtain the number of threads:

C/C++: int omp_get_num_threads(void)

Fortran: integer function omp_get_num_threads()

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Obtain the thread number

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Fortran: integer function omp_get_thread_num()

Notice thread 0 is the master!

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C/C++: int omp_get_num_procs(void)
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Set the number of threads

C/C++: void omp_set_num_threads(int number_threads)
Fortran: subroutine omp_set_num_threads(number_threads)

More for you to find

https://computing.llnl.gov/tutorials/openMP/

http://openmp.org/wp/openmp-specifications/

Still More?

More About MPI

MPI defines a library for C, Fortran and Java. MPI's definition includes no specific features of any manufacturer, OS or device.

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Especially, MPICH environment is broadly accepted.

MPICH Download

http://www.mcs.anl.gov/research/projects/mpich2

Compile in MPICH

- mpicxx/mpicc/mpif77/mpif90
- -cc=icc/gcc designates a specific compiler

Launch a MPI program

mpiexec -n N routine

mpiexec -host HOST_1 -n N routine_1 : -host HOST_2 -n M routine_2

Message Envelope for Sender

MPI_Send(address,count,datatype,destination,tag,communicator)

Description

address: data pointer
count: length of datatype
datatype: unified data type in MPI
destination: ID of process receiver
tag: for programmer use
communicator: ID of communication group

Message Envelope for Receiver

MPI_Recv(address,count,datatype,source,tag,communicator,status)

Description

status: a pointer of datatype MPI_Status, which record the information of sending and receiving

Broadcast

MPI_Bcast(address,count,datatype,root,comm)

Scatter

For Root:

MPI_Scatter(send_address,send_count,send_datatype,root,comm)

For others:

MPI_Scatter(recv_address,recv_count,recv_datatype)

Gather

For Root:

MPI_Gather(recv_address,recv_count,recv_datatype,root,comm)

For others:

MPI_Gather(send_address,send_count,send_datatype)

Barrier

MPI_Barrier(comm)

Description

Let processes in the same communicator wait for each other.

More for you to find

http://www.mcs.anl.gov/research/projects/mpi/

Not Finished Yet?

About GPU Programming

So far, we have not mentioned CUDA programming yet.

CUDA is so *unfriendly* that I would not address here.

More for you to find

http://www.nvidia.com/object/cuda_home_new.html

Advanced Tips for HPC?

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Q&A

Any Question?

Epilogue

Thanks for your Attention!