

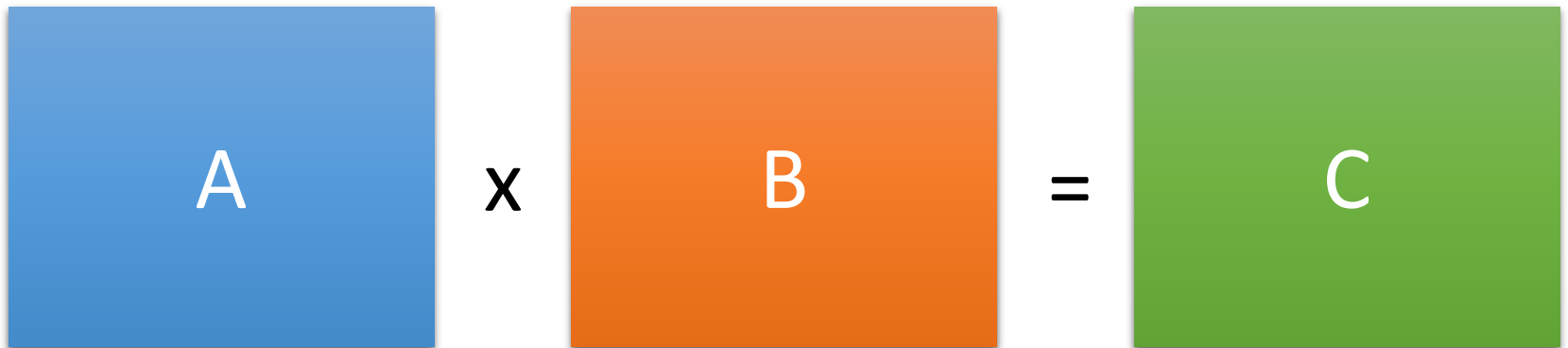
# Programming Assignment #2 -- Multi-Process Matrix Multiplication using Shared Memory

Introduction to Operating Systems

Prof. Li-Pin Chang@NCTU

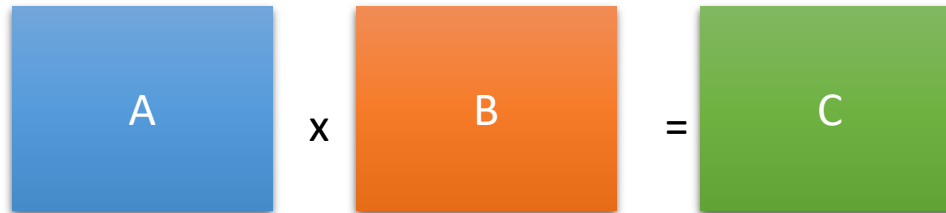
# Overview

- Matrix multiplication using multiple processes
  - Basic parallel processing
  - Will be faster on multicore machines
- Input: the dimension of two square matrices A & B
  - E.g., 100  $\rightarrow$  A, B, and C are 100x100 square matrices
- Output: an execution time and a checksum

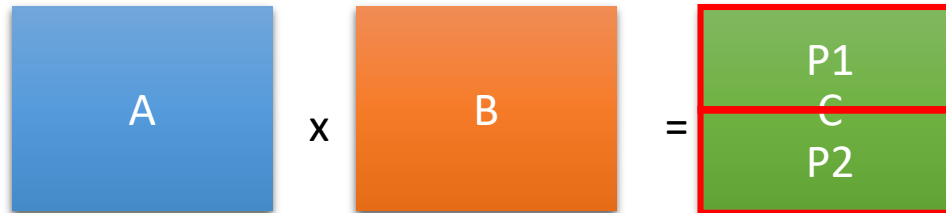


# Task Partition

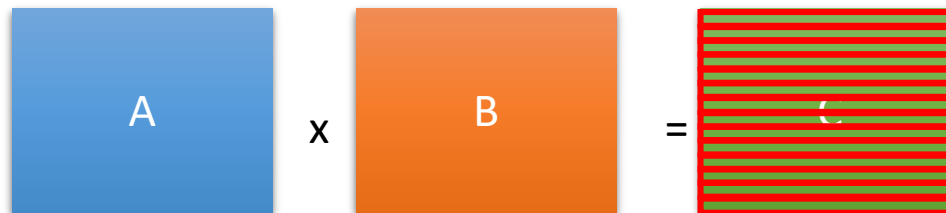
- 1-process matrix multiplication



- 2-process matrix multiplication

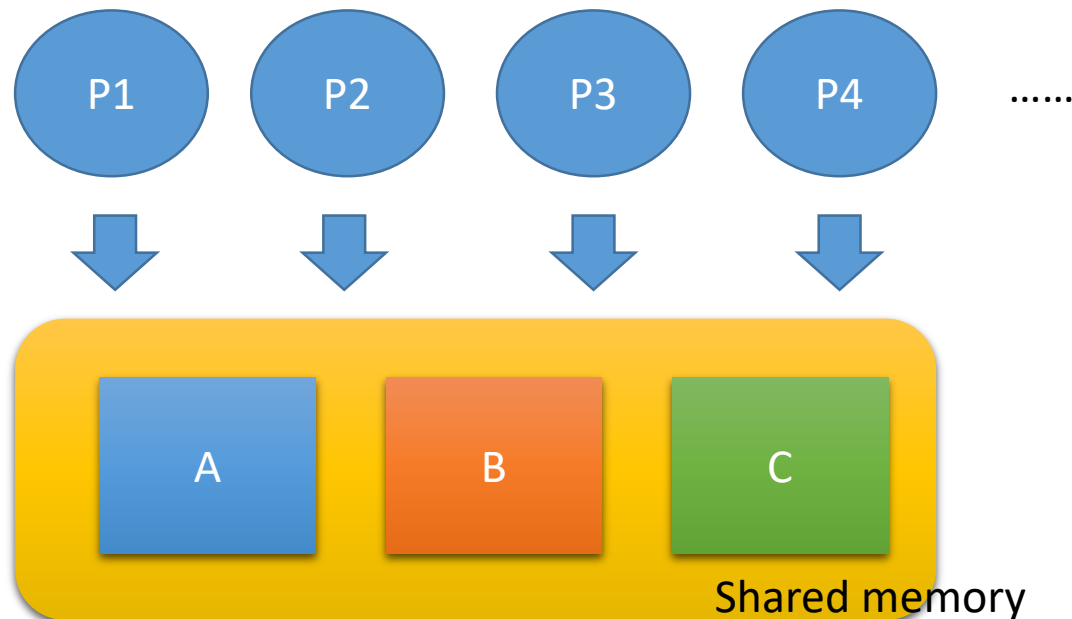


- 16-process matrix multiplication



# Shared Memory

- Matrices A, B, and C are stored in a shared memory
- **No** locking/synchronization is required since multiplication on sub-metrics are mutually independent



# Header Files

- `unistd.h`
- `sys/ipc.h`
- `sys/shm.h`
- `sys/wait.h`
  
- `sys/time.h`

# APIs

- `shmget()` – create a block of shared memory
- `shmat()` – attach shared memory to the current process's address space
- `shmdt()` – detach shared memory from the current process's address space
- `shmctl()` – control shared memory
- `gettimeofday()`

# shmget()

- `int shmget(key_t key, size_t size, int shmflg);`
- create a block of shared memory
- Return the **id of the request shm** of size equals to the value of `size`
- `key` : 0/IPC\_PRIVATE for new allocate shm
- `size` : size in bytes
- `shmflg` : IPC\_CREAT | mode\_flags(9 bits)  
e.g. IPC\_CREAT | 0600 for read only shm

# shmat()

- `void *shmat(int shmid, const void *shmaddr, int shmflg);`
- Attach shared memory to the current process's address space
- Return the address of the attached shared memory segment identified by *shmid*
- *shmaddr* : NULL for system to choose suitable address
- *shmflg* : 0 for read/write, **SHM\_RDONLY** for read only



# shmdt()

- `int shmdt(const void *shmaddr);`
- Detach the shared memory segment located at the address *shmaddr* from the address space of the calling process
- *shmaddr* must equal to the value returned by `shmat( )`

# shmctl()

- `int shmctl(int shmid, int cmd, struct shmids *buf);`
- control shared memory
- Perform control operation
  - `IPC_STAT`
  - `IPC_SET`
  - `IPC_RMID`
  - ...
- **IPC\_RMID:** Marking a shared memory to be deleted. The share memory will be destroyed on when the last process detach the memory from its address space. Must be called by the creator of the shared memory.

# gettimeofday()

```
struct timeval start, end;  
gettimeofday(&start, 0);  
//do something  
gettimeofday(&end, 0);  
int sec = end.tv_sec - start.tv_sec;  
int usec = end.tv_usec - start.tv_usec;  
  
printf("elapsed %f ms", sec*1000+(usec/1000.0));
```

# Matrix Initial Values

- Matrix elements in A and B are initialized as follows (for example, an 8x8 matrix)

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

Checksum of this matrix: 2016

# Requirements

- Create worker processes using `fork()`
  - Wait until all worker processes have `exit()`'ed
- Put all the metrics in the shared memory
- Print the elapsed time and matrix checksum
  - 16 cases, process parallelism from 1 to 16
  - The final checksum must be correct
  - Matrix elements and the checksum are 32-bit unsigned integers
  - Do not worry about integer overflows
- TAs will test your program using any matrix dimension between 100\*100 and 800\*800
- TAs will test your program on a multicore machine (VM)
  - Your 2-process and 3-process versions must be noticeably faster than your 1-process version
- Violating any of these requirements will incur a score penalty

# Output

Input the matrix dimension: 800↵

Multiplying matrices using 1 process

Elapsed time: 5.814723 sec, Checksum: 561324032

Multiplying matrices using 2 processes

Elapsed time: 3.10231 sec, Checksum: 561324032

Multiplying matrices using 3 processes

Elapsed time: 2.927338 sec, Checksum: 561324032

.....

Multiplying matrices using 16 processes

Elapsed time: x.xxxxx sec, Checksum: 561324032

# API Reference

- <http://blog.csdn.net/guoping16/article/details/6584058>
- <http://man7.org/linux/man-pages/man2/shmget.2.html>
- <http://man7.org/linux/man-pages/man2/shmat.2.html>

# Testing OS Environment

- Ubuntu 16.04, Ubuntu 14.04 or CS linux work station
  - Your code should compile successfully in one of the above environments