Review

Inter-Process Communication
- Race Condition
- Critical Section (or region)
- Solutions for Mutual Exclusion in a Critical Section
  - With Busy Waiting
    - Disabling Interrupts –non-preemptive kernel
    - Lock Variables –violating the first necessary condition (mutual exclusion)
    - Strict Alternation –violating the second necessary condition (block by a process outside critical section)
    - Peterson's Solution
    - Hardware Solution
      - Test and Set Lock –
      - Memory Barriers
      - Atomic Variable
    - Priority Inversion problems with busy waiting

Preview

- Mutual Exclusion in a Critical Section
  - With Sleep and Wake up
    - Producer Consumer Problem
    - Race Condition Producer Consumer problem
    - Semaphore
      - Concept of Semaphore
      - Semaphore Operation
      - Semaphore Implementation
      - Producer Consumer problem with semaphores
      - Careless Usage of semaphore causes deadlock
    - Dining Philosophers Problem
    - Reader's and Writer's Problem
    - Mutexes
    - Monitor
      - Implementation of Monitor
      - Producer Consumer with Monitor
    - Message Passing
      - Producer Consumer with Message Passing

Mutual Exclusion with Sleep and Wakeup

- Sleep and Wakeup-
  - A process check a resource (critical section), if not available go to sleep.
  - When the resource become available, the process will be waked up by system or the process release the resource.

The Producer-Consumer Problem

Description
- Two processes share a common, fixed-sized buffer.
- Producer puts information into the buffer, and consumer takes it out.

Troubles arises
- When the producer wants to put a new item in the buffer, but it is already full.
- When the consumer tries to take a item from the buffer, but buffer is already empty.

The Producer-Consumer Problem

- When the producer wants to put a new item in the buffer, but it is already full.
  - Solution – producer is go to sleep, awakened by customer when customer has removed on or more items.
- When the consumer tries to take a item from the buffer, but buffer is already empty.
  - Solution – customer is go to sleep, awakened by the producer when producer puts one or more information into the buffer.

The Producer-Consumer Problem

```
#define N 100 //buffer size
int count = 0;//# of item
void producer()
{
   int item
   while (true)
   {
        item = produce_item();
        if (count == N)
             sleep();
        insert_item(item)
        count = count + 1;
        if (count ==1)
             wakeup(consumer);
   }
}
```

```
void consumer()
{
   int item;
   while(true)
   {
        if (count == 0)
             sleep();
        item = remove_item();
        count = count - 1;
        if (count == N - 1)
             wakeup(producer);
        consume_item(item);
   }
}
```

Semaphores – by E. W. Dijkstra

- A semaphore is an integer variable which could have value
  - 0: no wakeups are saved
  - + i: i wakeups are pending
- A semaphore is accessed only through two standard atomic operations *down* (or P) and *up* (or V).

Concept of Semaphores

- Modification to the integer value of the semaphore in the down and up operations are executed indivisibly.
- Which means that when a process is modifying the semaphore value, no other process can simultaneously modify that same semaphore value.

Semaphore Operation

```
void down (S)
{
   if S == 0
   {
1. Add this process to the sleeping list
2. block;
   }
   S = S – 1;
}
```

```
void up (S)
{
   S = S + 1;
   If S = 1
   {
1. choose one process P from the sleeping list or let them move to ready state
2. wakeup(P) to finish down operation
   }
}
```


Semaphore Implementation

The normal way for implementing a semaphore

- Implement semaphore operations ***up*** and ***down*** as system call.
- operating system briefly disabling all interrupts while it is testing the semaphore, updating it and putting the process to sleep.

Solving the Producer-Consumer Problem using Semaphores

```
#define N 100
typedef int semaphore;
semaphore mutex = 1;  //mutual exclusion
semaphore empty = N; // empty space
semaphore full = 0; // number of item
void producer ()
{
    int item;

    while (ture)
    {
        item = produce_item(); //produce item
        down (&empty); //check empty space
        down (&mutex); //check mutual exclusion
        insert_item(item); //insert item
        up(&mutex); //out from critical section
        up(&full); //increase # of item
    }
}
```

```
void consumer()
{
    int item;

    while (true)
    {
        down(&full); //check item in buffer
        down(&mutex) //check mutual exclusion
        item = remove_item(); //remove a item
        up(&mutex); //out from critical section
        up(&empty); //increase the empty space
        consume_item(item);
    }
}
```


Careless usage of Semaphore causes deadlock

```
#define N 100
typedef int semaphore;
semaphore mutex = 1; //mutual exclusion
semaphore empty = N; // empty space
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void producer ()
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    int item;

    while (ture)
    {
        item = produce_item();
        down (&mutex);
        down (&empty);
        insert_item(item);
        up(&mutex);
        up(&full);
    }
}
```

```
void consumer()
{
    int item;

    while (true)
    {
        down(&full)
        down(&mutex)
        item = remove_item();
        up(&mutex);
        up(&empty);
        consume_item(item);
    }
}
```

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   }
}
```

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void consumer()
{
   int item;

   while (true)
   {
         down(&mutex);
         down(&full);
         item = remove_item();
         up(&mutex);
         up(&empty);
         consume_item(item);
   }
}
```


Dining Philosophers Problem

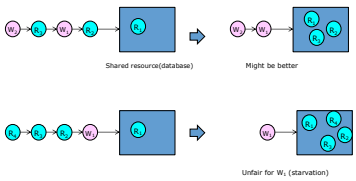
Dining Philosophers Problem

- Five silent philosophers sit at a round table with bowls of spaghetti. Chopsticks are placed between each pair of adjacent philosophers.
- Each philosopher must alternately think and eat. However, a philosopher can only eat spaghetti when they have both left and right chopsticks.
- Each chopstick can be held by only one philosopher and so a philosopher can use the chopstick only if it is not being used by another philosopher.
- After an individual philosopher finishes eating, they need to put down both chopsticks so that the chopstick s become available to others. A philosopher can take the chopstick on their right or the one on their left as they become available, but cannot start eating before getting both chopsticks.

Readers-Writers Problem

- Process reader R and writers W are sharing resources at one time. Only one process (reader or writer) can access the shared resources at any time.
  1. It is possible that a reader R_1 might have the lock to a shared resource, and then another reader R_2 requests access. It would be foolish for R_2 to wait until R_1 was done before starting its own read operation; instead R_1 and R_2 can read same resource at the same time since both are reading.
  2. It is possible that a reader R_1 might have the lock, a writer W be waiting for the lock, and then a reader R_2 requests access. It would be unfair for R_2 to jump in immediately, ahead of W; if that happened often enough, W would starve.

Readers-Writers Problem



Mutexes

- When the semaphore's ability to count is not needed, the simplified version of the semaphore, called mutex is used.
- It is good for managing a mutual exclusion to some shared resources or pieces of code
- It is useful in thread packages that are implemented in user's space.
- A mutex is a variable that can be in one of two state: unlocked (0), locked(1).
- A mutex concept is same as binary semaphore which has value 0 or 1.

Mutexes

```
mutexes mutex = 0
repeat
   mutex_lock (mutex);
                Critical Section
   mutex_unlock (mutex);
                Remainder Section
   until false
```


Monitor

- Monitor – High level synchronizing primitive
  - A collection of procedures, variables, and data structures that are all grouped together in a special kind of module.
  - Only one process can be active in a monitor at any instant.
  - Compiler knows that monitors are special and can handle calls to monitor procedure differently from other procedure call (create special code for monitor).
  - When a process call a procedure inside a monitor,
    1. check whether any process is active within monitor or not.
    2. If so, the calling process will be suspended until the other process has left the monitor.

Implementation of Monitor

- Since monitor is a **construct** for a programming language, Monitor implementation is based on the compiler
- Compiler knows monitor is special kind of module, compiler use mutex or binary semaphore for mutual exclusion.
- Monitor provide an easy way to achieve mutual exclusion. But we need to consider, how a process can be blocked and how blocked process can be waked up?
  - Introduction of Condition variables

Implementation of Monitor

- Conditional variables are used in the monitor.
- There are two operation on the conditional variables (***wait***, ***signal***).
- When a monitor procedure discovers that it cannot continue, it does *wait* on some condition variable (ex full). This action causes the calling process to **block**. – allows other process get into the monitor.
- Other process (ex. consumer) can *wake* up its sleeping partner by doing a *signal* on the condition variable that its partner is waiting on.
- If there are more than one processes are waiting on a condition variable, system scheduler choose one of them

Implementation of Monitor

Once a process do a signal, what is next step for the process do a signal, to avoid having two active processes in the monitor at the same time?

Solution 1) by Hoare
- Letting the newly awakened process run, suspending the one do the signal

Solution 2) by Brinch Hansen
- A signal statement may appear only as the final statement in a monitor procedure.

Producer-Consumer with Monitor

```
monitor ProducerConsumer
condition full, empty;
integer count;
procedure insert (item: integer);
begin
      if count = N then
            wait (full);
      insert_item(item);
      count :=count + 1;
      if count = 1 then
            signal (empty)
end;

function remove: integer;
begin
      if count = 0 then
            wait (empty);
      remove = remove_item;
      count := count - 1;
      if count = N - 1 then
            signal (full);
end;
count := 0;
end monitor
```

```
procedure producer
begin
      while true do
      begin
            item = produce_item;
            ProducerConsumer.insert(item)
      end
end;

procedure consumer;
begin
      while true do
      begin
            item = ProducerConsumer.remove;
            consume_item(item)
      end
end;
```

Message Passing

- Message Passing is a method of interprocess communication by using two primitive system calls
  - send(destination, &message);
  - receive(source, &message);
- Usually Message Passing is used between processes located in different system since it is slower than using semaphore or monitor in the same system.
- If there is no message is available, the receiver will be blocked by system until one arrived.
- If there is no message to send, the sender will be blocked by system until one become available.

Message Passing
(Design Issues for Message Passing System)

- Message can be lost
  - Solution:
    - When a message is received, receiver send acknowledgement message.
    - If sender has not received the ack. message within a certain time interval, retransmits the message.
  - This solution cause new design issue.
- Receiver receive a message from sender, receiver send Ack. message. If the Ack. message lost, sender send same message again. Then receiver receive same message twice.
  - Solution:
    - Each message is assigned with sequence number.
    - Receiver site system can recognize duplicated message and discard one of them.

Producer-Consumer Problem
(with Message Passing)

```
#define N 100                                   /* number of slots in the buffer */
void producer ()
{
    int item;
    message m;                                  /* message buffer */
    while (ture)
    {
        item = produce_item();                  /* generate item to put in buffer */
        receive(consumer, &m);                  /* wait for an empty slot (ACK)*/
        build_message(&m, item);                /* construct a message to send */
        send(consumer, &m);                     /* send item to consumer */
    }
}
```

```
void consumer()
{
    int item, i;
    message m;
    for (i=0; i < N; i++)                       /* send N empty messages*/
        send(producer, &m);
    while (true)
    {
        receive(producer, &m);                  /* receive a message from producer */
        item = extract_item(&m);                /* extract a message */
        send(producer, &m)                      /* send an empty message to producer (ACK)*/
        consume_item(item);
    }
}
```