

# Assignment 2 Notes

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## 1 Read and Writer

- Reader don't modify the data so we can have multiple readers, but only one writer
- Are examples of a common computing problem in concurrency
- Is a part of semaphore problem

## 2 Product/Consumer

```
producer() {
    while(1) {

        add_to_buf()

    }
}

consumer() {
    while(1) {

        remove_from_buf()

    }
}
```

- Is essentially how `pipes()` are implemented
- Has bounded buffer as a shared variable
  - Bounded buffer is also used when piping the output of one program into another

### Example

```
grep foo file.txt | wc -l
```

\* `grep`

- searches the input files for lines containing a match to a given pattern
- when it finds a match in a line, it copies the line to standard output (by default)

\* `wc -l`

- stands for word count
- is used to find the number of lines (in this case)

\* `grep` is the producer

\* `wc` is the consumer

- Single buffer producer/consumer solution

- Is to use two different conditinal variables
  - \* Is nice, trouble free and simple

```

1  cond_t  empty, fill;
2  mutex_t mutex;
3
4  void *producer(void *arg) {
5      int i;
6      for (i = 0; i < loops; i++) {
7          Pthread_mutex_lock(&mutex);
8          while (count == 1)
9              Pthread_cond_wait(&empty, &mutex);
10         put(i);
11         Pthread_cond_signal(&fill);
12         Pthread_mutex_unlock(&mutex);
13     }
14 }
15
16 void *consumer(void *arg) {
17     int i;
18     for (i = 0; i < loops; i++) {
19         Pthread_mutex_lock(&mutex);
20         while (count == 0)
21             Pthread_cond_wait(&fill, &mutex);
22         int tmp = get();
23         Pthread_cond_signal(&empty);
24         Pthread_mutex_unlock(&mutex);
25         printf("%d\n", tmp);
26     }
27 }

```

Conditional variable 1

Conditional variable 2

YES

```

1  int loops;
2  cond_t  cond;
3  mutex_t mutex;
4
5  void *producer(void *arg) {
6      int i;
7      for (i = 0; i < loops; i++) {
8          Pthread_mutex_lock(&mutex);           // p1
9          while (count == 1)                    // p2
10             Pthread_cond_wait(&cond, &mutex); // p3
11         put(i);                                // p4
12         Pthread_cond_signal(&cond);           // p5
13         Pthread_mutex_unlock(&mutex);         // p6
14     }
15 }
16
17 void *consumer(void *arg) {
18     int i;
19     for (i = 0; i < loops; i++) {
20         Pthread_mutex_lock(&mutex);           // c1
21         while (count == 0)                    // c2
22             Pthread_cond_wait(&cond, &mutex); // c3
23         int tmp = get();                      // c4
24         Pthread_cond_signal(&cond);           // c5
25         Pthread_mutex_unlock(&mutex);         // c6
26         printf("%d\n", tmp);
27     }
28 }

```

Same conditional variable

NONO

- The general correct producer/consumer solution

```

1  int buffer[MAX];
2  int fill_ptr = 0;
3  int use_ptr = 0;
4  int count = 0;
5
6  void put(int value) {
7      buffer[fill_ptr] = value;
8      fill_ptr = (fill_ptr + 1) % MAX;
9      count++;
10 }
11
12 int get() {
13     int tmp = buffer[use_ptr];
14     use_ptr = (use_ptr + 1) % MAX;
15     count--;
16     return tmp;
17 }
18
19 ~
20 cond_t empty, fill;
21 mutex_t mutex;
22
23 void *producer(void *arg) {
24     int i;
25     for (i = 0; i < loops; i++) {
26         Pthread_mutex_lock(&mutex);           // p1
27         while (count == MAX)                  // p2
28             Pthread_cond_wait(&empty, &mutex); // p3
29         put(i);                               // p4
30         Pthread_cond_signal(&fill);           // p5
31         Pthread_mutex_unlock(&mutex);         // p6
32     }
33 }
34
35 void *consumer(void *arg) {
36     int i;
37     for (i = 0; i < loops; i++) {
38         Pthread_mutex_lock(&mutex);           // c1
39         while (count == 0)                    // c2
40             Pthread_cond_wait(&fill, &mutex); // c3
41         int tmp = get();                      // c4
42         Pthread_cond_signal(&empty);          // c5
43         Pthread_mutex_unlock(&mutex);         // c6
44         printf("%d\n", tmp);
45     }
46 }

```

Changes made to make solution general

### 3 Conditional Variable

```

lock_acquire(lock);
while(condition not true) {
    cv_wait(cond, lock);
}
... // do stuff
cv_signal(cond); //or cv_broadcast(cond)
lock_release(lock);

```

Condition

Conditional variable

- is a queue of waiting threads

- has two operations associated with it:
  1. `cv_wait(struct cv *cv, struct lock *lock)`
    - Is executed when a thread wishes to put itself to sleep
    - Releases lock, waits, re-acquires lock before return
      - \* Is to prevent race conditions from occurring when a thread is trying to put itself to sleep
  2. `cv_signal(struct cv *cv, struct lock *lock)`
    - Wakes one enqueued thread
  3. `cv_broadcast(struct cv *cv, struct lock *lock)` [from notes]
    - Wakes all enqueued threads
- If no one is waiting, signal or broadcast has no effect
- has rules
  - always use with while loops
    - \* on waking up, thread checks for condition in while loop
    - \* if condition is true, then thread goes back to sleep
- is always used together with locks

### 3.1 Example 1: Read/Writer Problem (Using CV)

```

//number of readers
int readcount = 0;

// Only one writer allowed.
/* No reader while writer is
writing*/

Writer {
    Write;
}

// Multiple readers
/* Readers don't modify any
data */
Reader {
    Read;
}

```

- The problem is about updating and checking the value

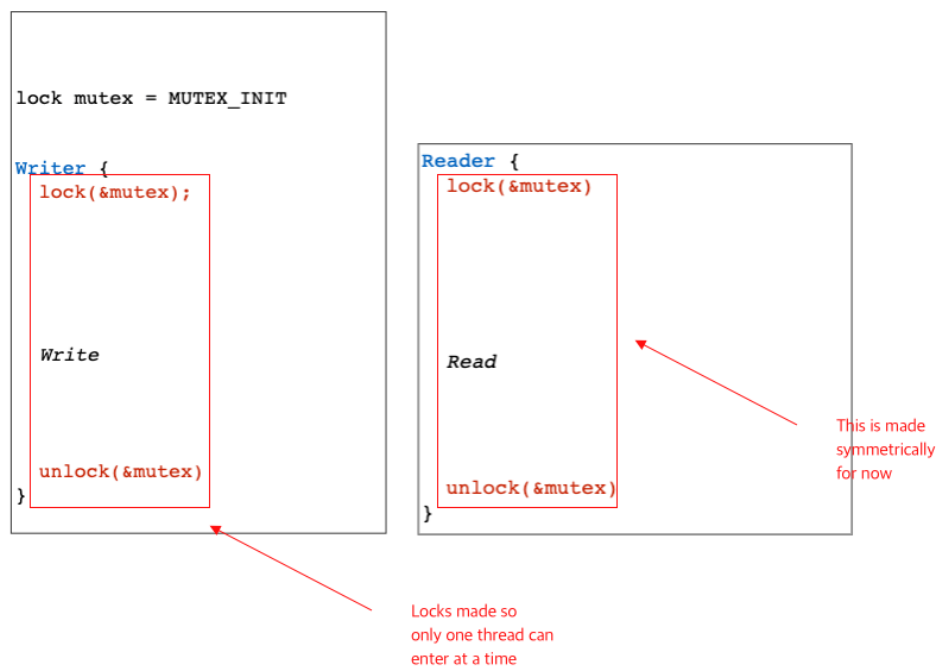
#### Example

Updating values or reading values in database

- Goals
  - Want only one writer at a time so the writing data is always correct
    - \* One reader + One writer or multiple writer creates a problem (race condition)
  - Want many readers at a time because they don't get each other in the way
- Is complex
  - Lots of overhead
- Steps (from lectures)

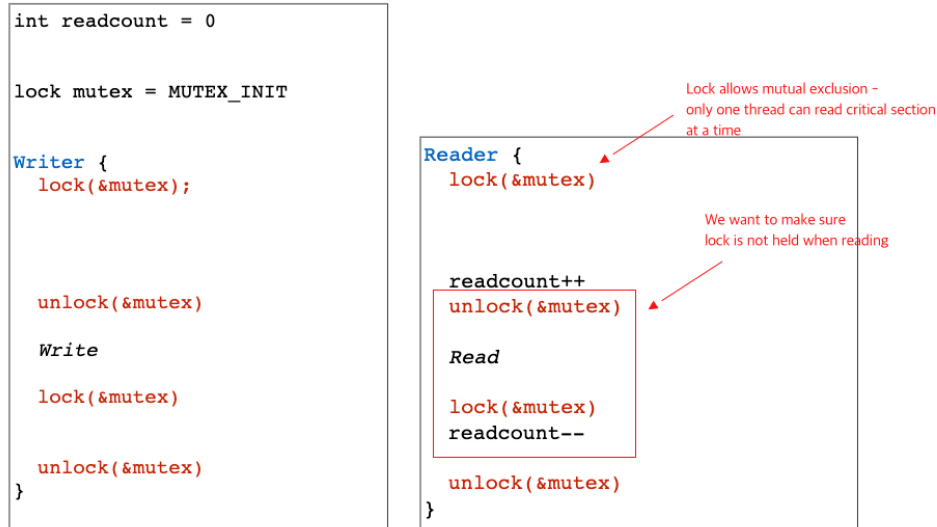
### Step 1

- is about making sure only one thread in writer can enter at a time
- symmetric locks in reader are made for now



### Step 2

- is about making sure we are not holding the lock while we are reading
- symmetric locks in writer are made for now



### Step 3

- is about making sure write doesn't proceed when read is in process

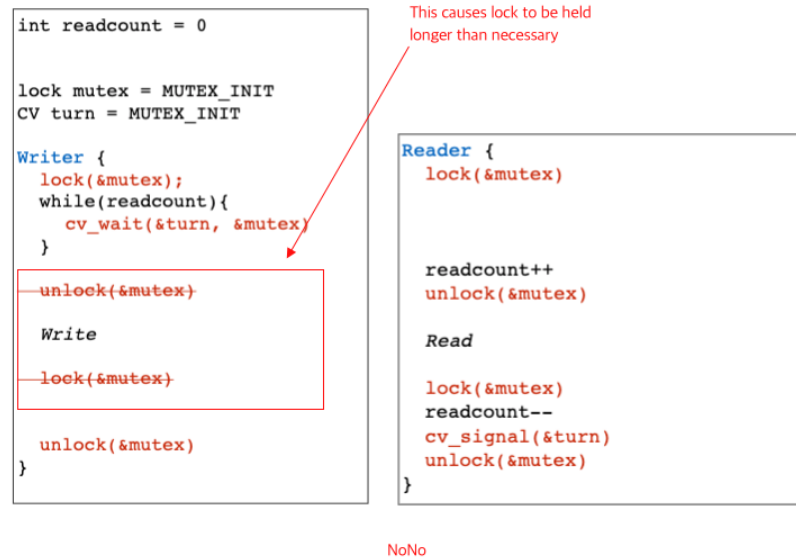


- We can use mutex in reader before critical section because lock in write is released under `cv_wait(...)`

### Step 3.5

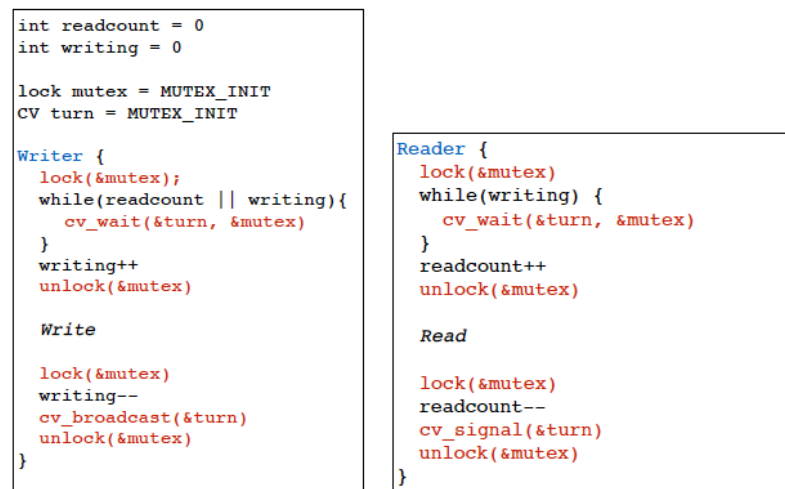
- suppose we try to remove inner lock (to remove extra overhead)
  - \* Causes starvation!! not good
    - Reader can keep coming and increase readcount, causing writer to be in blocked state
  - \* then we hold lock longer than necessary (Not what we want!!)

- we don't want to hold lock longer than necessary



#### Step 4

- The purpose is to not hold writing as long as possible
- Solves starvation
  - \* Done by adding conditional variable in reader



#### Step 5

- Think when thread blocked on **turn** wakes up in each reader and writer, can the condition be true?

### Step 6

- Think what would happen when we use **signal** or **broadcast**?
  - \* New ones in read could bypass the while loop and go into read
  - \* Could result in starvation (Nono)
  - \* We only want one thread to go in

```

int readcount = 0
int writing = 0

lock mutex = MUTEX_INIT
CV turn = MUTEX_INIT

Writer {
    lock(&mutex);
    while(readcount || writing){
        cv_wait(&turn, &mutex)
    }
    writing++
    unlock(&mutex)

    Write

    lock(&mutex)
    writing--
    cv_broadcast(&turn)
    unlock(&mutex)
}

```

```

Reader {
    lock(&mutex)
    while(writing) {
        cv_wait(&turn, &mutex)
    }
    readcount++
    unlock(&mutex)

    Read

    lock(&mutex)
    readcount--
    cv_signal(&turn)
    unlock(&mutex)
}

```

## 4 Deadlock

- Conditions
  - Mutual exclusion [Necessary Condition]
    - \* only one process may use a resource at a time
  - Hold and wait [Necessary Condition]
    - \* A process may hold allocated resources while awaiting assignment of others
  - No preemption [Necessary Condition]
    - \* No resource can be forcibly removed from a process holding it
    - \* You can't steal lock from another thread
  - Circular wait [Sufficient Condition]
    - \* No resource can be forcibly removed from a process holding it

### Example

- A is holding lock x
- B is awaiting for lock x to be released
- B is holding lock y
- A is awaiting for lock y to be released

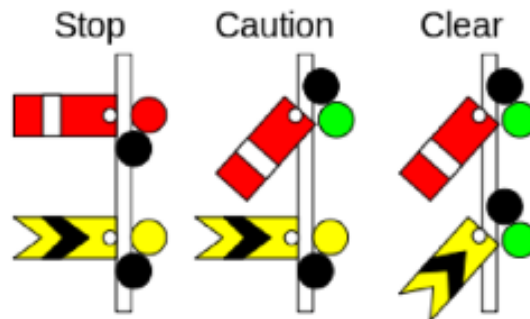


## 5 Semaphore

```
Wait(Sem){
    while(Sem <= 0) ;
    Sem--;
}
```

```
Signal(Sem){
    Sem++;
}
```

- Was first invented by Dijkstra
- Is abstract data types that provide synchronization



- Has two atomic operations
  - wait
    - \* Is also called P or decrement
    - \* waits if value of count is negative
  - signal
    - \* increments the variable, unblock a waiting thread if there are any
    - \* wakes one thread if there are one or more threads waiting
- Has two types
  1. Binary semaphore (count = 0 or 1)
    - Has single access to a resource
    - Can be used like a lock
      - \* Provides mutual exclusion to a critical section
    - Needs to have initial value of 1
      - \* Is for decrementation of count in `sem_wait()`

```

1  sem_t m;
2  sem_init(&m, 0, X); // initialize to X; what should X be?
3
4  sem_wait(&m); // Decreases the value of count by 1
5  // critical section here
6  sem_post(&m); // Increases the value of count by 1

```

Need to initialize semaphore to 1

Value of Semaphore	Thread 0	Thread 1
1		
1	call sem_wait()	
0	sem_wait() returns	
0	(crit sect)	
0	call sem_post()	
1	sem_post() returns	

## 2. Counting semaphore

- Resource with many units available
- Is resource that allows certain kinds of unsynchronized concurrent access (e.g. reading)
- Mutex has count = 1, counting has count = N

## 3. Implementation Tips

- Implement as few constraints as possible (e.g. how many semaphores do you need to solve the problem?)

## 5.1 Example 1: Producer/Consumer (Using semaphore)

```

1  void *producer(void *arg) {
2      int i;
3      for (i = 0; i < loops; i++) {
4          sem_wait(&mutex); // Line P0 (NEW LINE)
5          sem_wait(&empty); // Line P1
6          put(i);           // Line P2
7          sem_post(&full);  // Line P3
8          sem_post(&mutex); // Line P4 (NEW LINE)
9      }
10 }
11
12 void *consumer(void *arg) {
13     int i;
14     for (i = 0; i < loops; i++) {
15         sem_wait(&mutex); // Line C0 (NEW LINE)
16         sem_wait(&full);  // Line C1
17         int tmp = get();  // Line C2
18         sem_post(&empty); // Line C3
19         sem_post(&mutex); // Line C4 (NEW LINE)
20         printf("%d\n", tmp);
21     }
22 }

```