

Semaphores and a shared buffer

- recall our previous example from last week which had two processes
 - one process calls `put` and another process calls `get`
- both operate on a shared buffer
 - we use a semaphore called `Mutex` to protect the buffer

Semaphores and a shared buffer

```
void put (char ch)      char get (void)
{
    Wait (Mutex)        Wait (Mutex)
    (* safe to alter *)  (* safe to alter *)
    (* buffer           *) (* buffer           *)
    place ch into buf    remove ch from buf

    Signal (Mutex)       Signal (Mutex)

                                return ch;
}

char buffer[Max]; (* global data *)
SEMAPHORE Mutex;  (* global data *)
```

Semaphores and a shared buffer

- what happens if a process calls `get` before a process calls `put`?
- there is no character to take from the buffer
 - there is no data to return
- what happens if a process keeps calling `put` and no process calls `get`
 - potentially the buffer will be overrun

Semaphores and a shared buffer

- both cases can be fixed by using two additional semaphores
- if there is no character in the buffer and we call `get` then we should *wait* until data arrives
- if there is no space in the buffer and we attempt to `put` a character into the buffer then we should *wait* until space becomes available

Semaphores and a shared buffer

- we can implement this with two semaphores, which we will declare as
 - `itemAvailable`
 - `spaceAvailable`

Semaphores and a shared buffer

- before we place a character into a buffer we must
`wait(spaceAvailable)`
- before we extract a character from a buffer we must
`wait(itemAvailable)`
- after we place an item into the buffer we must
`signal(itemAvailable)`
- after we extract an item from the buffer we must
`signal(spaceAvailable)`

Semaphores and a shared buffer

- what are their initial values for an empty buffer?
 - for simplicity let us assume the buffer can hold four characters
 - `itemAvailable` 0
 - `spaceAvailable` 3

- this buffer mechanism is known as Dijkstra's bounded buffer after its author E.W. Dijkstra who discovered the algorithm in 1960s

Completed implementation of a shared buffer using semaphores

```
void put (char ch)      char get (void)
{
    wait(spaceAvailable)  wait(itemAvailable)
    wait(mutex)           wait(mutex)
    (* safe to alter *)   (* safe to alter *)
    (* buffer             *)   (* buffer             *)
    place ch into buf     remove ch from buf

    signal(mutex)         signal(mutex)
    signal(itemAvailable)  signal(spaceAvailable)
                           return ch;
}

char buffer[Max]; (* global data *)
SEMAPHORE mutex;  (* global data *)
```


Completed implementation of a shared buffer using semaphores

- if one process keeps calling `put` and another process calls `get` we see that both processes are synchronising against taking data from an empty buffer and also from putting data into a full buffer

Readers and writers problem and semaphores

- another common classic problem in operating systems is solving the readers/writers problem
- here the problem is defined as some common resource needs to be protected such that
 - multiple readers can read from the resource simultaneously
 - only one writer can write to the resource at a time
 - a writer must wait for all readers to finish reading before it can alter the resource

Readers and writers problem and semaphores

- how to solve this with the minimal amount of semaphores?
- this problem is common among databases or game servers
- we use a `mutex` semaphore to protect the other data structures used in our lock
- we use another semaphore `writers` to queue multiple writers trying to access the shared resource
- we use an integer count to count the number of readers reading from the resource `readcount`

Readers and writers problem and semaphores

- the writer processes can be implemented by:

```
writers = semaphore (value = 1)

while True:
    ...
    wait(writers)
    # the process can now write to the shared resource
    signal(writers)
    ...
```

Readers and writers problem and semaphores

- the reader process can be implemented by:

Readers and writers problem and semaphores

```
mutex = semaphore (value = 1)
readcount = 0

while True:
    ...
    wait(mutex)
    readcount = readcount+1
    if readcount == 1:    # first reader waits as a writer
        wait(writers)
    signal(mutex)
    # reader can read the shared resource
    wait(mutex)
    readcount = readcount-1
    if readcount == 0:    # last reader signals as a writer
        signal(writers)
    signal(mutex)
    ...
```

Interprocess communication: Message passing

- message passing is another form of Interprocess Communication
- it allows processes to communicate and to synchronise their actions without sharing the same address space
- a message passing facility provides at least two operations
 - `send(message)` and `receive(message)`
- some message passing libraries allow for variable sized data to be sent/received and other allow a fixed amount of data to be send/received
 - tradoffs between complexity of implementation of the library and complexity of the user program

Interprocess communication: Message passing

- the message passing libraries also may be further complicated by how a process addresses another process
- consider
- | |
|--------------------------------------------------------------------------------------------------------------------------|
| <pre>send(P, message) # send a message to process P
received(Q, message) # receive a message from process Q</pre> |
|--------------------------------------------------------------------------------------------------------------------------|
- we describe these primitives as having symmetry in addressing
 - that is both processes need to know the name of the other to receive and send a message

Interprocess communication: Message passing

- other library implementations might use asymmetric naming for process addressing, consider:

- | | |
|-----------------------------------|----------------------------------------------------|
| <code>send(P, message)</code> | <code># sends a message to process P</code> |
| <code>receive(id, message)</code> | <code># receive a message from any process,</code> |
| | <code># id will contain the processes, name</code> |

Conclusion

- we have seen how semaphores can be used to solve some classic computer science problems
 - readers/writers and shared buffer
- we have explored the message passing paradigm