CSCI315 – Operating Systems Design

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Synchronization Tools: semaphores

Ch 6.6

This set of notes is based on notes from the textbook authors, as well as L. Felipe Perrone, Joshua Stough, and other instructors.
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Issue With the Lock Solution

- While **locks** (and other hardware-based solutions we discussed in last segment) do well to ensure the exclusive access to shared data, the solution is simplistic.
  - It may result in "busy waiting," not a good use of resources.
  - It is possible that the waiting time is not bounded as we cannot control the order with locks.

Semaphores

- **Semaphore** – an abstract data type consisting of two parts, a counter and a queue, working together to provide atomic operations

- **Counting semaphore** – the counter value is unlimited

- **Binary semaphore** – the counter can only be 0 or 1; it can be simpler to implement (also known as **mutex** locks).

- Provides **mutual exclusion**:

```
semaphore S(1);  // initialized to 1
wait(S);         // or acquire(S) or P(S)
criticalSection();
signal(S);       // or release(S) or V(P)
```

Semaphore Implementation

```
typedef struct {
  int value;
  struct process_t *list;
} semaphore;
```

It looks like a normal C variable, except that operations on semaphores are **atomic**, just like what we saw in **test_and_set()** and **compare_and_swap()** to ensure the integrity of the value.

Semaphore Implementation

```
wait(semaphore *S) { // try to enter
    S->value--;
    if (S->value < 0) { // others in CR
            add the process to S->list;
            sleep();    // or wait()
     }
}
```

These two operations have to be **atomic**!

```
signal(semaphore *S) { // leave
    S->value++;
    if (S->value <= 0) { // others waiting
            remove a process P from S->list;
            wakeup(P);  // or signal()
    }
}
```

Here **wait()** is also known as the **P** operation, and **signal()** as **V**. These are Dutch words were given by Dijkstra, a world-renowned Dutch-native computer scientist, who invented the notion.

https://en.wikipedia.org/wiki/Semaphore_(programming)#Operation_names

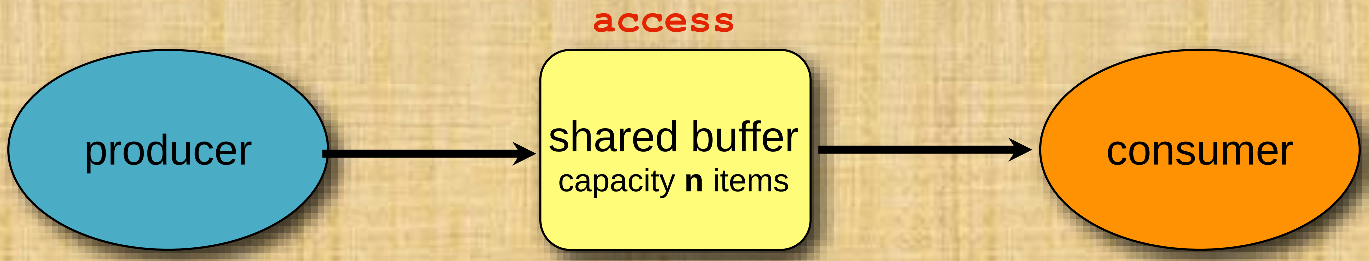
The Bounded-Buffer Problem

Binary semaphore

Counting semaphore

```
int n;
mutex access;
semaphore empty;
semaphore full;
```

```
init(&access,1);
init(&empty,n);// wait for space
init(&full,0); // wait for item
```

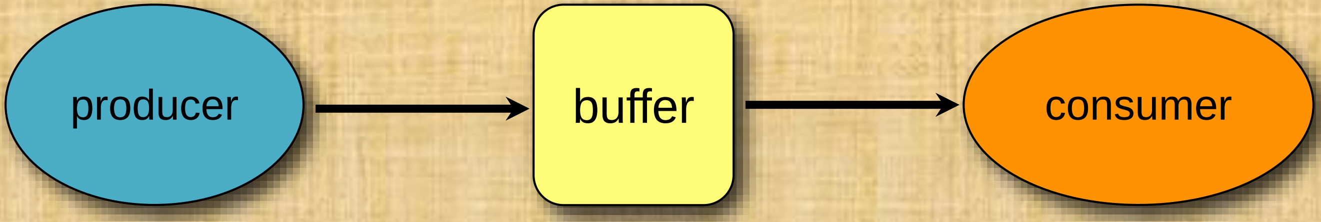


Why do we initialize **access** to be 1?
Why **empty** be n?
Why **full** be zero?

The Bounded-Buffer Problem

```
do {// produce item and save
    wait(&empty);
    wait(&access);
    // add item and save
    signal(&access);
    signal(&full);
} while (true);
```

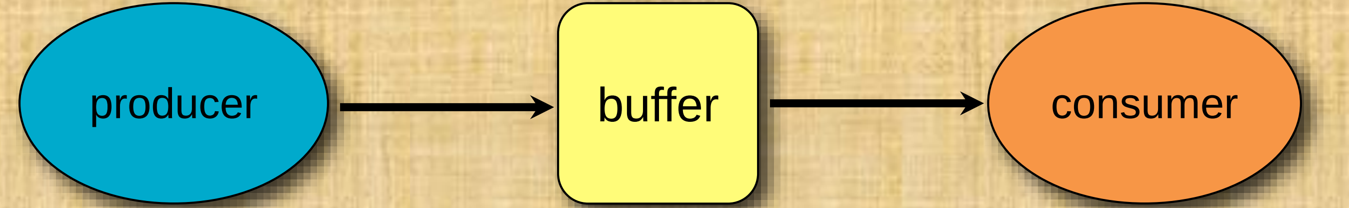
Producer



The Bounded-Buffer Problem

```
do {// produce item and save
     wait(&empty);
     wait(&access);
     // add item and save
     signal(&access);
     signal(&full);
} while (true);
```

critical section



producer

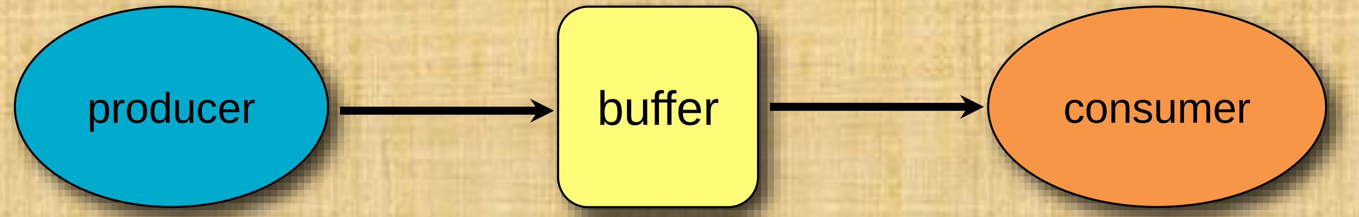
buffer

consumer

The Bounded-Buffer Problem

Consumer

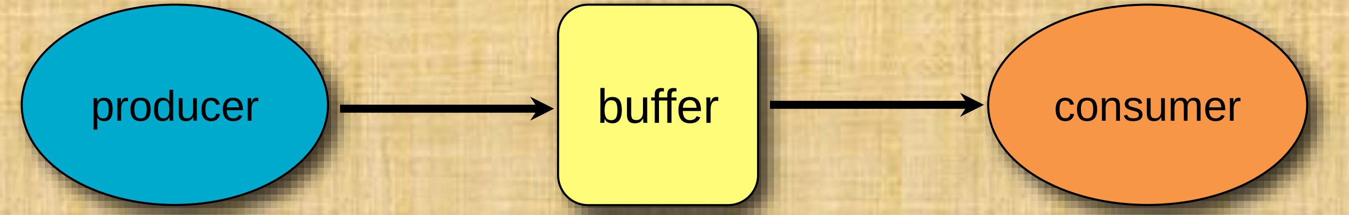
```
do {
        wait(&full);
        wait(&access);
        // remove item and save
        signal(&access);
        signal(&empty);
        // consume save item
} while (true);
```



The Bounded-Buffer Problem

Critical Section

```
do {
       wait(&full);
       wait(&access);
       // remove item and save
       signal(&access);
       signal(&empty);
       // consume save item
} while (true);
```



Monitor

- Semaphores are low-level synchronization resources.
- A programmer's honest mistake can compromise the entire system (well, that is almost always true). We should want a solution that reduces the risk.
- The monitor is one such data type:

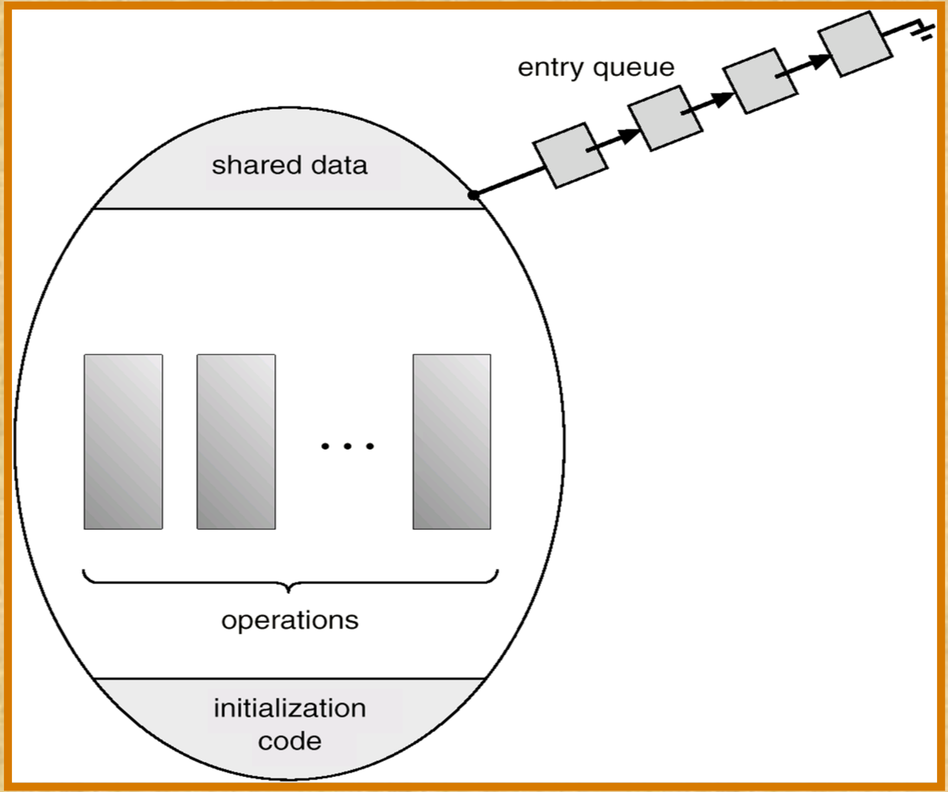
```
monitor mName {
   // declare shared variables
   procedure P1 (…) {
       …
   }
   procedure Pn (…) {
       …
   }
   init code (…) {
      ….
   }
}
```

A *procedure* can access only local variables defined within the monitor.

There cannot be concurrent access to procedures within the monitor (only one process/thread can be *active* in the monitor at any given time).

Condition variables: queues are associated with variables. Primitives for synchronization are wait and signal.

Monitor


entry queue
shared data
. . .
operations
initialization
code