CS 4410
Operating Systems

Synchronization
Classic Problems

Summer 2013

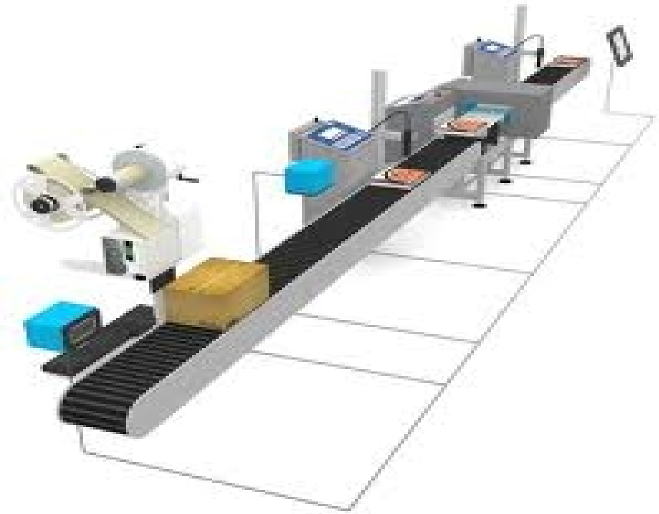
Cornell University

Today

- What practical problems can we solve with semaphores?
- Bounded-Buffer Problem
- Producer-Consumer Problem

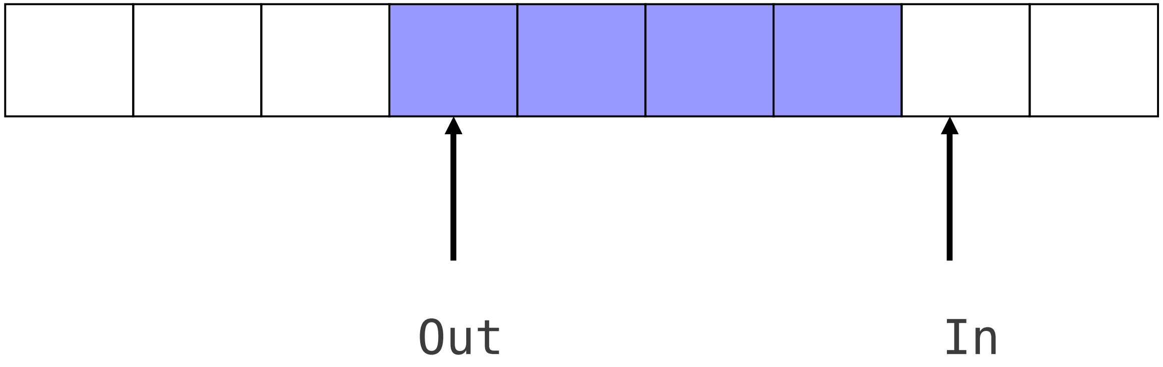
Producer-Consumer Problem

- Arises when **two or more threads communicate** with each other.
- And, some threads “**produce**” data and other threads “**consume**” this data.
- Real example: Production line



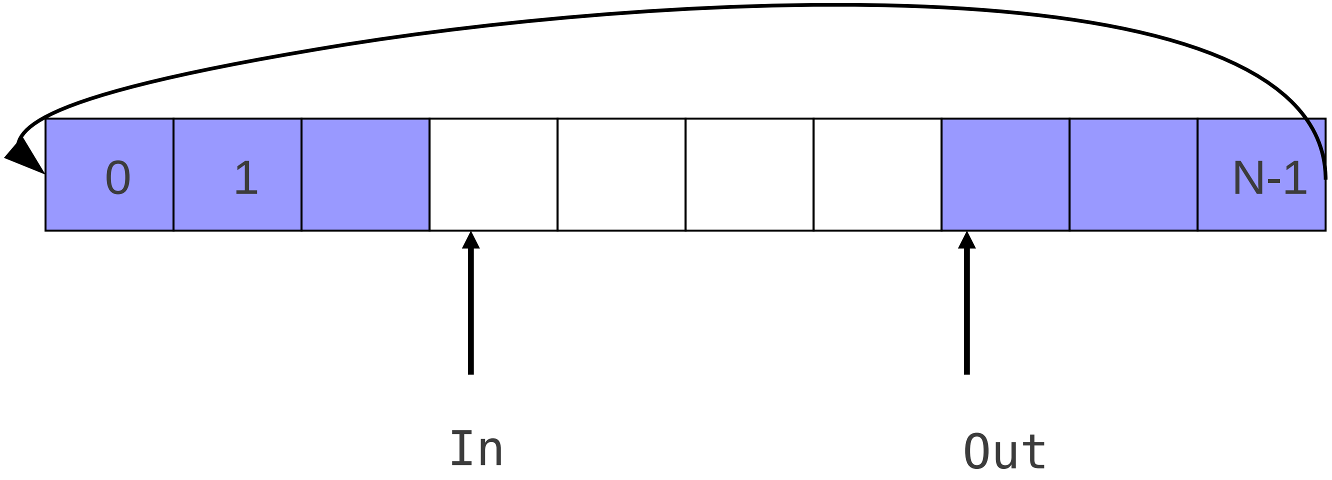
Producer-Consumer Problem

- Start by imagining an unbounded (infinite) buffer
  - Producer process writes data to buffer
    - Writes to `In` and moves rightwards
  - Consumer process reads data from buffer
    - Reads from `Out` and moves rightwards
    - Should not try to consume if there is no data



Producer-Consumer Problem

- Bounded buffer: size ‘N’
  - Access entry 0… N-1, then “wrap around” to 0 again
- Producer process writes data to buffer
  - Must not write more than ‘N’ items more than consumer “ate”
- Consumer process reads data from buffer
  - Should not try to consume if there is no data



Producer-Consumer Problem

- Multiple producer-threads.
- Multiple consumer-threads.
- One bounded buffer with N entries.
- All threads modify the same buffer.
- Requirements:
  - No production when all N entries are full.
  - No consumption when no entry is full.
  - Only one thread should modify the buffer at any time.

Producer-Consumer Problem

- Solving with semaphores:
  - We’ll use *counters* to track how much data is in the buffer
    - One counter counts as we add data and stops a producer if there are N objects in the buffer.
    - A second counter counts as we remove data and stops a consumer if there are 0 in the buffer.
  - Idea: since general semaphores can count for us, we don’t need a separate counter variable.
  - We'll use a mutex to protect the update of the buffer (“In” and “Out” pointers).

Producer-Consumer Problem

```
Shared pointers: “In”, “Out”
Shared Semaphores: mutex, empty, full;

        mutex = 1;  /* for mutual exclusion*/
        empty = N;  /* number empty buf entries */
        full = 0;   /* number full buf entries */
```

Producer

```
do {


      //produce item
      //update “In”


} while (true);
```

Consumer

```
do {


      //consume item
      //update “Out”


} while (true);
```

Producer-Consumer Problem

```
Shared pointers: “In”, “Out”
Shared Semaphores: mutex, empty, full;

        mutex = 1;  /* for mutual exclusion*/
        empty = N;  /* number empty buf entries */
        full = 0;   /* number full buf entries */
```

Producer

```
do {
    wait(empty);

      //produce item
      //update “In”

    signal(full);
} while (true);
```

Consumer

```
do {
    wait(full);

      //consume item
      //update “Out”

    signal(empty);
} while (true);
```

Producer-Consumer Problem

```
Shared pointers: “In”, “Out”
Shared Semaphores: mutex, empty, full;

        mutex = 1;  /* for mutual exclusion*/
        empty = N;  /* number empty buf entries */
        full = 0;   /* number full buf entries */
```

Producer

```
do {
    wait(empty);
    wait(mutex);
      //produce item
      //update “In”
    signal(mutex);
    signal(full);
} while (true);
```

Consumer

```
do {
    wait(full);
    wait(mutex);
      //consume item
      //update “Out”
    signal(mutex);
    signal(empty);
} while (true);
```

Readers and Writers

- In this problem, threads share data that some threads “read” and other threads “write”.

- Goal: allow **multiple** concurrent **readers** but only a **single writer** at a time, and if a writer is active, readers wait for it to finish.

Readers-Writers Problem

- Access to a database
  - A **reader** is a thread that needs to look at the database but won’t change it.
  - A **writer** is a thread that modifies the database.
- Making an airline reservation
  - When you browse to look at flight schedules the web site is acting as a reader on your behalf.
  - When you reserve a seat, the web site has to write into the database to make the reservation.

Readers-Writers Problem

- Many reader-threads.
- Many writer-threads.
- One piece of data.
- Multiple threads try to access that data.
- Requirements:
  - Multiple readers may access the data at the same time.
  - If a writer accesses the data, no other thread may access the data.
- What happens when multiple readers and one writer are waiting to access the data?

Readers-Writers Problem

```
mutex = Semaphore(1)
wrt = Semaphore(1)
readcount = 0;
```

Writer

```
do{

    /*writing is performed*/

}while(true)
```

Reader

```
do{

    /*reading is performed*/

}while(true)
```

Readers-Writers Problem

```
mutex = Semaphore(1)
wrt = Semaphore(1)
readcount = 0;
```

Writer

```
do{
    wait(wrt);
    /*writing is performed*/
    signal(wrt);
}while(true)
```

Reader

```
do{



        wait(wrt);

    /*reading is performed*/



        signal(wrt);

}while(true)
```

Readers-Writers Problem

```
mutex = Semaphore(1)
wrt = Semaphore(1)
readcount = 0;
```

Writer

```
do{
    wait(wrt);
    /*writing is performed*/
    signal(wrt);
}while(true)
```

Reader

```
do{
    wait(mutex);
    readcount++;
    if (reardcount == 1)
        wait(wrt);
    signal(mutex);
    /*reading is performed*/
    wait(mutex);
    readcount--;
    if (readcount == 0)
        signal(wrt);
    signal(mutex);
}while(true)
```

Readers-Writers Notes

- If there is a writer
  - First reader blocks on **`wrl`**
  - Other readers block on **`mutex`**
- Once a reader is active, all readers get to go through
  - Which reader gets in first?
- The last reader to exit signals a writer
  - If no writer, then readers can continue
- If readers and writers are waiting on **`wrl`**, and writer exits
  - Who gets to go in first?
- Why doesn’t a writer need to use **`mutex`**?
- Is the previous solution fair?
- Readers can “starve” writers!
- Building a “fair” solution is tricky!

Today

- Which practical problems can we solve with semaphores?
- Producers-Consumers Problem
- Readers-Writers Problem