Inter-Process Communication

Issues

- How a process can pass information to another
- Make sure processes don't get into each others' way
- Sequencing and dependencies

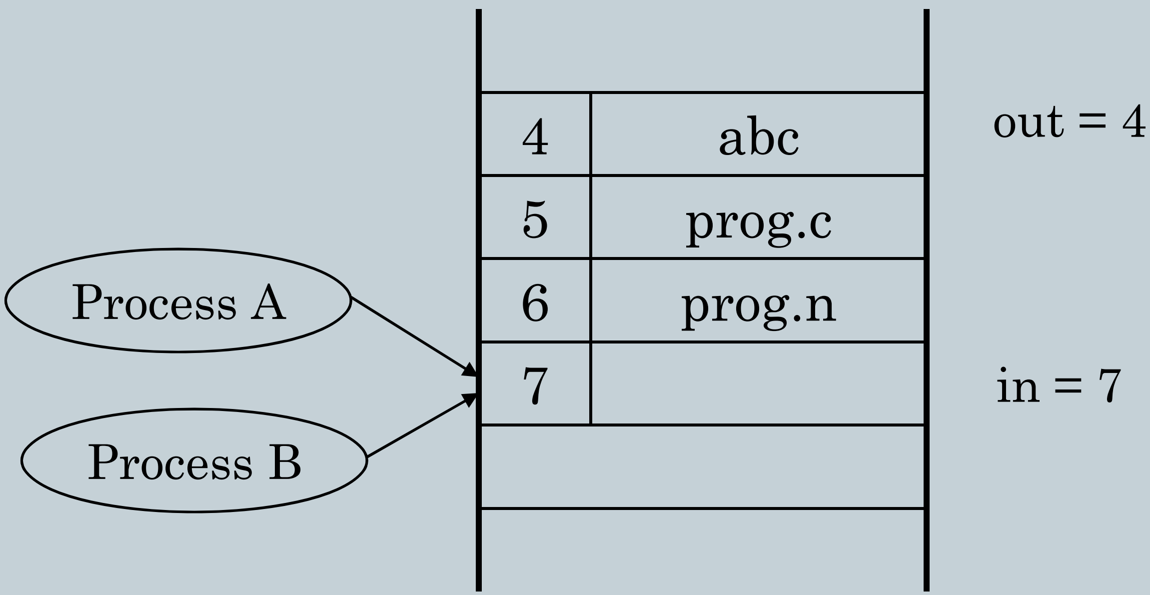
The issues…

- They apply to threads as well

- Communication: easy for threads (common address space)
- Remaining two issues apply to thread as to processes

Race condition

- Example: printer spooler (a daemon)



Spooler directory

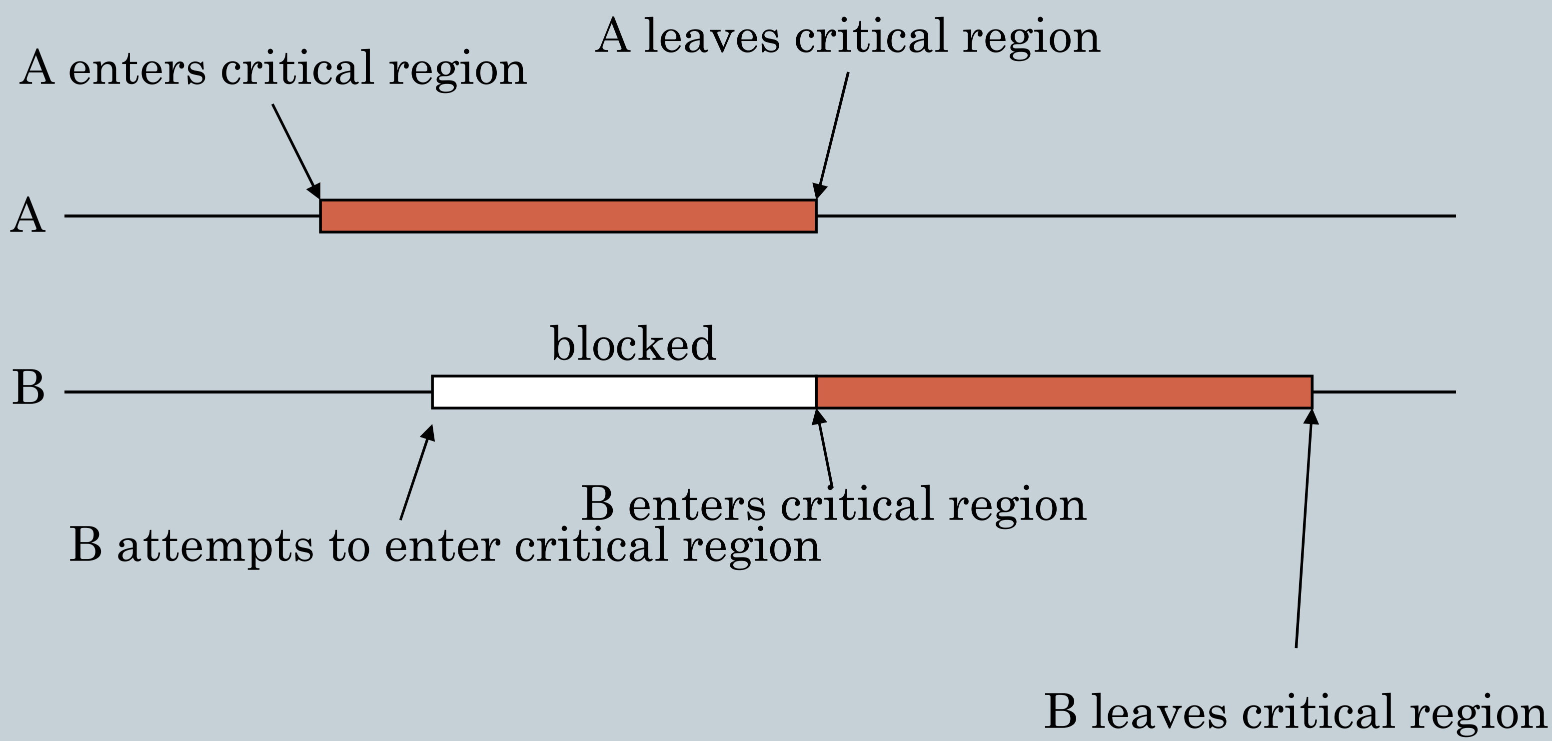
Race condition

- Two processes reading/writing on the same data and the result depends on who runs precisely when is called a *race condition*
- Since obviously we'd like computation to be deterministic

Critical regions

- *Mutual exclusion*
- The part of the program where the shared memory (or something else) is accessed is called a *critical section*
- This is not enough (more rules):
  - Not two processes simultaneously in their critical regions
  - No assumptions may be made about speed and number of CPUs
  - No process running outside its critical region may block another process
  - No process should have to wait forever to enter its critical region

Ideally


A enters critical region
A leaves critical region
A
blocked
B
B enters critical region
B attempts to enter critical region
B leaves critical region

Many solutions…

- Disabling interrupts
- Locks
- TSL instruction (hardware)
- Semaphores
- Mutexes
- Monitors
- Message passing
- …

Disabling interrupts

- Simplest solution
- CPU switches from process to process only when an interrupt occurs (e.g. the clock interrupt)
- This approach can be taken by the kernel
- Should the OS trust the user in disabling/enabling interrupts? Too dangerous!

Locks

- A lock variable (alone it doesn’t work)
- Strict alternation (no two in the critical region, not convenient)

```
while (TRUE)
{
  while (turn!=0);
  critical_region();
  turn = 1;
  noncritical_region();
}
```

```
while (TRUE)
{
  while (turn!=1);
  critical_region();
  turn = 0;
  noncritical_region();
}
```

Peterson's solution


```
#define FALSE 0
#define TRUE 1
#define N 2

int turn;
int interested[N];        // initialized = 0

void enter_region(int process)
{
  int other;
  other = 1 – process;
  intereseted[process] = TRUE;
  turn = process;
  while (turn == process && interested[other] == TRUE) ;
}

void leave_region(int process)
{
  interested[process] = FALSE;
}
```

TSL instruction

- TSL RX, LOCK (test and set lock)
- Reads the content of LOCK into RX and stores a non-zero value into LOCK atomically (can't be interrupted)

Example


```
enter_region:
  TSL REGISTER, LOCK
  CMP REGISTER, #0
  JNE enter_region
  RET

leave_region:
  MOVE LOCK, #0
  RET
```

Semaphores

- An **atomically** accessible counter. Similar to a lock but with multiple values and possibly blocking a process without busy-waiting
- There are two operations possible:
  - Up, Down
- Down, if 0 the process will go to sleep otherwise it decrements the semaphore and continues execution
- Up, increments the semaphore, if a process is sleeping on the semaphore, it is awakened, the caller never blocks

Example consumer-producer


```
#define N 100
typedef int semaphore; /// with a bit of\ imagination

semaphore mutex = 1;
semaphore empty = N;
semaphore full = 0;

void producer(void)
{
  int item;
  while (TRUE)
  {
    item = produce_item();
    down(&emty);
    down(&mutex);
    insert_item(item);
    up(&mutex);
    up(&full);
  }
}
```

```
void consumer(void)
{
  int item;
  while (TRUE)
  {
    down(&full);
    down(&mutex);
    item = remove_item();
    up(&mutex);
    up(&empty);
    consume_item(item);
  }
}
```

Mutexes

- Semaphores with binary values
- What’s nice? Simpler implementation than semaphores
- Of course, a semaphore can be made to behave as a mutex and vice-versa a mutex is enough to implement a semaphore

Monitors

- Abstract construct (a package):
  - It's a sort of class (in fact there's something similar in Java)
  - Monitor's data is *private*
  - Only one process can be **active** in a monitor at a given time
  - Condition variables: **wait** and **signal** primitives (equivalent to **down** and **up**)

Part of an example...


```
monitor ProducerConsumer
   condition full, empty;
   integer count;

   /// PROCEDURES_HERE()
   /// it's guaranteed that no process can change
   /// count at the same time, just need to check
   /// the full and empty conditions

   count = 0;
end monitor;
```

Message passing

- Why? Distributed systems for example
  - `send(destination, &message)`
  - `receive(source, &message)`

Issues with message passing

- Acknowledgement (message)
  - We need to be sure a message is not lost otherwise synchronization will go berserker
  - Message numbering
  - A good part of the study on computer networks
- Authentication
  - Make sure only who's supposed to receive the message actually receives it and vice-versa

Example of message passing


```
#define N 100

void producer(void)
{
  int item;
  message m;

  while (TRUE)
  {
    item = produce_item();
    receive(consumer, &m);
                       waits for an EMPTY
    build_message(&m, item);
    send(consumer, &m);
  }
}
```

```
void consumer(void)
{
  int item, i;
  message m;

  for (i=0;i<N;i++) send(producer, &m);
         sends N EMPTIES

  while (TRUE)
  {
    receive(producer, &m);
    item = extract_item(&m);
    send(producer, &m);
         send an EMPTY
    consume_item(item);
  }
}
```

Access to database

- Many readers
- Only one writer

- Issues: no write until all readers are out, but try not to accept other readers if a write is pending!

Dining philosophers