CS 3305A

CPU Scheduling – Multiprocessor

Lecture 11
Multiple-Processor Scheduling

- So far, we've only dealt with a single processor

- CPU scheduling more complex when multiple CPUs are involved
Multiple-Processor Scheduling

- **Asymmetric multiprocessing** (master)
- There is one processor that makes the decisions for
  - Scheduling, I/O processing, system activities
  - Other processor(s) execute only user code.
- This is a simple approach due to master-slave model / centralized command model
- **Master CPU**: Load sharing
Multiple-Processor Scheduling

- Symmetric Multiprocessing (SMP)

- Here, each processor is self-scheduling.

- Share a common ready queue or each processor may have its own private queue of ready processes.

- Most modern operating systems support SMP including Windows XP, Solaris, Linux, and Mac OS X.
Process Synchronization - I

Lecture 11
Process Synchronization

- Race Condition
- Critical Section
- Mutual Exclusion
- Peterson’s Solution
- Disabling Interrupts
- Test and Lock Instruction (TSL)
- Semaphores
- Deadlock
Assume a spooler directory array (in shared memory) has a number of slots

- Numbered 0, 1, 2...
- Each slot has a file name

Two other variables:

- **In** points to the first empty slot where a new filename can be entered.
- **Out** points to the first non-empty slot, from where the spooler will read a filename and print the corresponding file.
Race Condition Example (1)

- Slots 1, 2, 3 are empty indicating the files in those slots have printed
- Each process has a local variable `next_free_slot` representing an empty slot
- Assume both process A and B want to print files.
  - Each wants to enter the filename into the first empty slot in spooler directory

<table>
<thead>
<tr>
<th>Spooler Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>
### Race Condition Example (1)

- Process A reads IN and stores the value 7 in its local variable, `next_free_slot`.
- Process A’s time quanta expires.
- Process B is picked as the next process to run.

**Diagram:**

```
<table>
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<tr>
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<tbody>
<tr>
<td>1</td>
</tr>
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<tr>
<td>8</td>
</tr>
</tbody>
</table>
```

- Process A’s next_free_slot variable is 4.
- Process B’s next_free_slot variable is 7.
Race Condition Example (1)

- Process B reads IN and stores the value 7 in its local variable, `next_free_slot`
- Process B writes a filename to slot 7
Race Condition Example (1)

- Process B then updates the In variable to 8
- Process A now gets control of the CPU
Race Condition Example (1)

- Process A writes its filename to slot 7 which erases process B’s filename.
- Process B does not get its file printed.
Race Condition (2)

- Application: Withdraw money from a bank account
- Two requests for withdrawal from the same account comes to a bank from two different ATM machines
- A thread for each request is created
- Assume a balance of $1000
Race Condition (2)

bank_example (account, amount_to_withdraw) {
    1. balance = get_balance(account);
    2. if (balance => amount_to_withdraw) 
        withdraw_authorized(); 
        else 
            withdraw_request_denied();
    3. balance = balance - amount_to_withdraw;
}

What happens if both requests request that $600 be withdrawn?
## Race Condition (2)

<table>
<thead>
<tr>
<th>Process / Thread 1</th>
<th>Process / Thread 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Read balance: $1000</td>
<td></td>
</tr>
<tr>
<td>2. Withdraw authorized for $600 (now actual balance is $400)</td>
<td></td>
</tr>
<tr>
<td>CPU switches to process 2→</td>
<td>3. Read Balance $1000</td>
</tr>
<tr>
<td>4. Withdraw authorized for $600 (this is unreal!!)</td>
<td></td>
</tr>
<tr>
<td>5. Update balance $1000-$600 = $400</td>
<td>← CPU switches to process 1</td>
</tr>
<tr>
<td>CPU switches to process 2→</td>
<td>6. Update balance $400-$600 = $-200</td>
</tr>
</tbody>
</table>
Critical Sections and Mutual Exclusion

- **A critical section** is any piece of code that accesses shared data
  - Printer example: In, Out variables are shared
  - Bank account: Balance is shared

- **Mutual exclusion** ensures that only one thread/process accesses the critical section at a time i.e., No two processes simultaneously in critical section!
Mutual Exclusion in Critical Sections

- Process A enters critical region at time $T_1$.
- Process A leaves critical region at time $T_2$.
- Process B attempts to enter critical region at time $T_3$.
- Process B enters critical region at time $T_4$.
- Process B leaves critical region at time $T_4$.
- Process B is blocked between $T_3$ and $T_4$.

Time progression:
- $T_1$: Process A enters critical region.
- $T_2$: Process A leaves critical region.
- $T_3$: Process B attempts to enter critical region.
- $T_4$: Process B enters critical region.
General structure for Mutual Exclusion

Do {
    entry section
    critical section
    exit section
    remainder section
} while(1)