CSE 373: Heaps
(application)

Chapter 6

Resource Management

Many of today’s examples will examine how resources can be shared between multiple users

- fairly...
- without wasting the resources...

This is a complex issue and it gets a great deal of study (queuing theory; operating systems)

Q: How well do you need to understand this?

A: Well enough to understand why we might use heaps (i.e., pay attention and “get it,” but don’t freak)
Application 1: Printer Queue

(Note: Most printer queues are actually FIFO)

The idea:
- you submit your document to the printer queue
- eventually, it gets its turn and prints out
- afterwards, the job is dropped (not needed again)

Imaginary Queue Policy:
- shorter print jobs should always print before longer ones (we’ll measure length by # pages)
- jobs with equal length should print in FIFO order

This looks like a job for a Heap!

while (1) {
  if (!printing) {
    Print(DeleteMin(PrintHeap));
  }
}

Q: How can we convert our policy to a numerical priority?
Printer Priority Scheme

Proposal: Priority = 1000 × (# pages) + counter

1) Maria prints a 2-page document
2) Brad prints a 30-page document
3) Sun Liang prints a 1-page document
4) Maria prints a 1-page document
5) Sun Liang prints a 1-page document

Problems with this scheme?
Why do people use FIFO?

Application 2: NQS

NQS: Network Queuing System

How it works:
- A supercomputer has 256 processors that can be used to run programs
- To use the computer, you must submit your program to NQS
- When submitting a program, you request a number of processors & an amount of time (e.g., 8 processors for 1 hour)
- Eventually, NQS will assign your job to a set of processors according to your request
- if your job doesn't complete in the time you requested, it is killed so that other programs may use the processors
- if it does complete in time, it's dropped
FIFO Queue Approach

For simplicity, we could just use a FIFO queue...

1) Maria submits a 32-processor, 20-minute job
2) Brad submits a 256-processor, 8-hour job
3) Sun Liang submits a 16-processor, 10-minute job
4) Maria submits an 8-processor, 25 minute job
5) Sun Liang submits an 8-processor, 15-minute job
6) Maria submits a 128-processor, 5 minute job

What’s the problem with using FIFO in this example?

FIFO visualization

UW, Spring 1999 CSE 373 – Data Structures and Algorithms Brad Chamberlain
**A Better Schedule**

```
<table>
<thead>
<tr>
<th>time</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

**“Smallest Job First” Heap**

Proposal: priority = job size

job size = \# processors \times requested time (in minutes)

What’s the problem with always running the “smallest” job first?

What’s the solution?
Application 3: Sharing a CPU

The idea:
- all computers have a CPU (e.g., Pentium-II) that can only run one program at a time
- to make it seem like many programs are running at once, the CPU takes turns running each for a short time (a quantum)
- some programs are more important than others and have higher priority
- programs waiting to be run can be kept on a heap
- CPU uses DeleteMin() to find the most important program
- if the program blocks while running, it’s put on a waiting list
- otherwise, once the quantum is up, it is re-Insert()ed

Shared CPU: Diagram
Shared CPU: Priorities

- User may select an initial priority
- Operating System may adjust priority if program hogs CPU or never gets to run
- What if we have multiple programs with the same (lowest) priority?

3 Programs, Same Priority

3 lowest:

or...

what next?
CPU Scheduling

- Tough problem
  - fairness vs. priority
  - must avoid starving processes
- Could modify priority based on lots of stuff:
  - how much a program has run vs. waited
  - how long it’s been in the queue
  - etc.
- But…it’s unclear (to me) whether a Priority Queue is really the best way to go...

Application 4: Simulations

Q: Let’s say we’ve designed a policy for any one of these applications. How could we evaluate it?
A: Could simulate an artificial workload:
  - set up a time scale (seconds, milliseconds, etc.)
  - keep track of events. For example:
    - a job is submitted to NQS
    - a job starts running
    - a job finishes running
  - submission time and running time are set (randomly?) by the workload
  - starting and finishing times depend on our scheduling policy
Simulations: Continued

- Could simulate time tick-by-tick:
  ```c
  while (1) {
    time++;
    for (job=0; job<numjobs; job++) {
      CheckForEvent(job, time);
    }
  }
  ```
  - **inefficient**, since there are more ticks than events
- Instead, keep a priority queue of events where events are prioritized by time
  - `DeleteMin()` will give us the next event

Simulations

sample workload:
- at \( t=0 \), Maria submits 32-proc, 20-min job
- at \( t=10 \), Brad submits a 256-proc, 8-hour job
- at \( t=20 \), Sun Liang submits a 16-proc, 10-min job
- at \( t=30 \), Maria submits an 8-proc, 25-min job

next event is Maria’s submission; policy says we should run Maria’s job at \( t=1 \)

etc.