The Abstract Data Type Queue

- A queue
  - New items enter at the back, or rear, of the queue
  - Items leave from the front of the queue
  - First-in, first-out (FIFO) property
    - The first item inserted into a queue is the first item to leave

The Abstract Data Type Queue

- Queues
  - Are appropriate for many real-world situations
    - Example: A line to buy a movie ticket
  - Have applications in computer science
    - Example: A request to print a document
  - A simulation
    - A study to see how to reduce the wait involved in an application

The Abstract Data Type Queue

- Pseudocode for the ADT queue operations
  (Continued)
  dequeue() throws QueueException
  // Retrieves and removes the front of a queue. Throws
  // QueueException if the operation is not successful.
  dequeueAll() // Removes all items from a queue
  peek() throws QueueException
  // Retrieves the front of a queue. Throws
  // QueueException if the retrieval is not successful
The Abstract Data Type Queue

<table>
<thead>
<tr>
<th>Operation</th>
<th>Queue after operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>queue.createQueue()</td>
<td></td>
</tr>
<tr>
<td>queue.enqueue(5)</td>
<td>5</td>
</tr>
<tr>
<td>queue.enqueue(2)</td>
<td>5 2</td>
</tr>
<tr>
<td>queue.enqueue(7)</td>
<td>5 2 7</td>
</tr>
<tr>
<td>queueFront = queue.peek()</td>
<td>queueFront is 5</td>
</tr>
<tr>
<td>queueFront = queue.dequeue()</td>
<td>queueFront is 5</td>
</tr>
<tr>
<td>queueFront = queue.dequeue()</td>
<td>queueFront is 2</td>
</tr>
</tbody>
</table>

Figure 8-2
Some queue operations

Simple Applications of the ADT Queue: Reading a String of Characters

- A queue can retain characters in the order in which they are typed
  ```
  queue.createQueue()
  while (not end of line) {
    Read a new character ch
    queue.enqueue(ch)
  }
  ```
- Once the characters are in a queue, the system can process them as necessary

Recognizing Palindromes

- A palindrome
  - A string of characters that reads the same from left to right as it does from right to left
- To recognize a palindrome, a queue can be used in conjunction with a stack
  - A stack can be used to reverse the order of occurrences
  - A queue can be used to preserve the order of occurrences

Recognizing Palindromes

- A nonrecursive recognition algorithm for palindromes
  - As you traverse the character string from left to right, insert each character into both a queue and a stack
  - Compare the characters at the front of the queue and the top of the stack

Implementations of the ADT Queue

- A queue can have either
  - An array-based implementation
  - A reference-based implementation

A Reference-Based Implementation

- Possible implementations of a queue
  - A linear linked list with two external references
    - A reference to the front
    - A reference to the back

Figure 8-4a
A reference-based implementation of a queue: a) a linear linked list with two external references
A Reference-Based Implementation

- Possible implementations of a queue (Continued)
  - A circular linked list with one external reference
    - A reference to the back

Figure 8-4b
A reference-based implementation of a queue: b) a circular linked list with one external reference

Figure 8-5
Inserting an item into a nonempty queue

A Reference-Based Implementation

Figure 8-6
Inserting an item into an empty queue: a) before insertion; b) after insertion

A Reference-Based Implementation

Figure 8-7
Deleting an item from a queue of more than one item

An Array-Based Implementation

• A circular array eliminates the problem of rightward drift

Figure 8-8
a) A naive array-based implementation of a queue; b) rightward drift can cause the queue to appear full

An Array-Based Implementation

Figure 8-9
A circular implementation of a queue
An Array-Based Implementation

Figure 8-10
The effect of some operations of the queue in Figure 8-8

An Array-Based Implementation

- A problem with the circular array implementation
  - front and back cannot be used to distinguish between queue-full and queue-empty conditions

An Array-Based Implementation

- To detect queue-full and queue-empty conditions
  - Keep a count of the queue items
- To initialize the queue, set
  - front to 0
  - back to MAX_QUEUE - 1
  - count to 0

An Array-Based Implementation

- Inserting into a queue
  back = (back+1) % MAX_QUEUE;
  items[back] = newItem;
  ++count;

- Deleting from a queue
  front = (front+1) % MAX_QUEUE;
  --count;
An Array-Based Implementation

- Variations of the array-based implementation
  - Use a flag `full` to distinguish between the full and empty conditions
  - Declare `MAX_QUEUE + 1` locations for the array items, but use only `MAX_QUEUE` of them for queue items

An Implementation That Uses the ADT List

- If the item in position 1 of a list `list` represents the front of the queue, the following implementations can be used
  - `dequeue()`
    `list.remove(1)`
  - `peek()`
    `list.get(1)`

The Java Collections Framework Interface `Queue`

- JCF has a queue interface called `Queue`
- Derived from interface `Collection`
- Adds methods:
  - `element`: retrieves, but does not remove head
  - `offer`: inserts element into queue
  - `peek`: retrieves, but does not remove head
  - `poll`: retrieves and removes head
  - `remove`: retrieves and removes head

Comparing Implementations

- All of the implementations of the ADT queue mentioned are ultimately either
  - Array based
  - Reference based
- Fixed size versus dynamic size
  - A statically allocated array
    - Prevents the `enqueue` operation from adding an item to the queue if the array is full
  - A resizable array or a reference-based implementation
    - Does not impose this restriction on the `enqueue` operation

Figure 8-12
A more efficient circular implementation: (a) a full queue; (b) an empty queue

Figure 8-13
An implementation that uses the ADT list
Comparing Implementations

- Reference-based implementations
  - A linked list implementation
    - More efficient
  - The ADT list implementation
    - Simpler to write

A Summary of Position-Oriented ADTs

- Position-oriented ADTs
  - List
  - Stack
  - Queue
- Stacks and queues
  - Only the end positions can be accessed
- Lists
  - All positions can be accessed

A Summary of Position-Oriented ADTs

- Stacks and queues are very similar
  - Operations of stacks and queues can be paired off as
    - createStack and createQueue
    - Stack isEmpty and queue isEmpty
    - push and enqueue
    - pop and dequeue
    - Stack peek and queue peek

Application: Simulation

- Simulation
  - A technique for modeling the behavior of both natural and human-made systems
  - Goal
    - Generate statistics that summarize the performance of an existing system
    - Predict the performance of a proposed system
  - Example
    - A simulation of the behavior of a bank

Figure 8-14a and 8-14b
A blank line at at time a) 0; b) 12
Application: Simulation

Figure 8-14c and 8-14d

A blank line at at time c) 20; d) 38

Figure 8-15

A typical instance of the event list

Application: Simulation

- An event-driven simulation
  - Simulated time is advanced to the time of the next event
  - Events are generated by a mathematical model that is based on statistics and probability
- A time-driven simulation
  - Simulated time is advanced by a single time unit
  - The time of an event, such as an arrival or departure, is determined randomly and compared with a simulated clock

Summary

- The definition of the queue operations gives the ADT queue first-in, first-out (FIFO) behavior
- A reference-based implementation of a queue uses either
  - A circular linked list
  - A linear linked list with a head reference and a tail reference
- An array-based implementation of a queue is prone to rightward drift
  - A circular array eliminates the problem of rightward drift

Application: Simulation

- The bank simulation is concerned with
  - Arrival events
    - Indicate the arrival at the bank of a new customer
    - External events: the input file specifies the times at which the arrival events occur
  - Departure events
    - Indicate the departure from the bank of a customer who has completed a transaction
    - Internal events: the simulation determines the times at which the departure events occur

Summary

- To distinguish between the queue-full and queue-empty conditions in a queue implementation that uses a circular array, you can
  - Count the number of items in the queue
  - Use a \textit{full} flag
  - Leave one array location empty
- Models of real-world systems often use queues
  - The event-driven simulation in this chapter uses a queue to model a line of customers in a bank
Summary

• Simulations
  – Central to a simulation is the notion of simulated time
    • In a time-driven simulation
      – Simulated time is advanced by a single time unit
    • In an event-driven simulation
      – Simulated time is advanced to the time of the next event
  – To implement an event-driven simulation, you maintain an event list that contains events that have not yet occurred