CSE 143

Queues, Event Lists, and Simulations

Chapter 7

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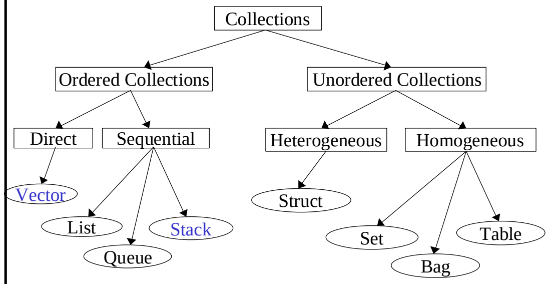
A Classification of ADTs



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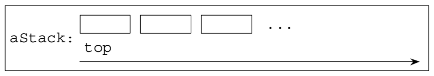
A Stack Definition (Review)

- Stack: "Homogeneous, ordered collection, accessed only at the front for removal and insertion"
  - *Top: last value in, first value out*



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When A Stack Is Not Quite Right

- People line up to use a pay phone
- There's only one place you leave the line (at the front, when the phone is free)
- There's only one place you enter the line (at the end -- everyone assumed to be polite!)
- The two places are different! So it's not a stack
- First in, first out: a "queue"

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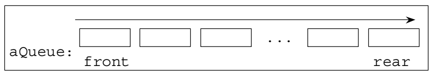
Queue Definition

- Queue: "Homogeneous, ordered collection, accessed only at the front (removal) and rear (insertion)"
  - *Front*: First element in queue
  - *Rear*: Last element of queue
- *FIFO*: First In, First Out



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Abstract Queue Operations

- *insert(item)* : Adds an element to rear of queue
  - succeeds unless the queue is full
  - often called "enqueue"
- *item remove( )* : Removes and returns element at the front of queue
  - succeeds unless the queue is empty
  - often called "dequeue"
- *item getFront( )* : Returns a copy of the front element of queue
  - succeeds unless the queue is empty
- No cursor, no iteration

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Queue Example

- Draw a picture and show the changes to the queue in the following example:

```
Queue q; int v1, v2;

q.insert(4);
q.insert(7);
q.insert(5);
v1 = q.remove();
v2 = q.getFront();
q.insert(9);
q.insert(2);
```

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What is the result of:

```
Queue q; int v1,v2,v3,v4,v5,v6
q.insert(1);
q.insert(2);
q.insert(3);
v1 = q.remove();
v2 = q.getFront();
q.insert(4);
v3 = q.remove();
v4 = q.getFront();
q.insert(5);
v5 = q.remove();
v6 = q.getFront();
```

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Queue vs. Stack

If I put a bunch of stuff in a queue or stack and then take it all out again...

- Queue: get it back in the original order
- Stack: get it back in reverse order

- Does this suggest an algorithm for checking palindromes??

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Common Uses of Queues

- Internal to a computer
  - Processes in an operating system, waiting for service (CPU, I/O, etc.)
  - Buffering input/output
    - When printing to screen with cout, characters don't appear right away: they are buffered and sent out in groups.
    - Print jobs at the printer
  - Mouse events needed to be handled
- Simulations
  - People or things waiting in line for service
  - More about this later

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Public Queue Interface

```
class IntQueue {  //see p.310
public:
   IntQueue( );            //should define a copy constructor, too
   bool isEmpty( );
   void insert(int item);
   int remove( );
   int getFront( );
private:
   // more than one way to do it.  Should the client care?
};
```

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Queue Implementations

- Choices similar to Stack
  - Array-based
  - Linked list
  - Existing Vector ADT implementation
- Queues are a little more complicated than Stacks
  - More complexity in the implementation
  - More ways to do it

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Queue Implementations

- Choices similar to Stack
  - Array-based
  - Linked list
  - Use existing Vector ADT

```
Convention: Rear is last position of vector
Convention: Front is always position 0
Quite straightforward, very few lines of code
```

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Another Implementation

- Choices similar to Stack
  - Array-based
  - Linked list
  - Exisiting Vector ADT implementation
- With L.L. we could follow Vector ADT pattern
  - Insert at end of linked list
  - Remove from front of list
  - A separate “rear” pointer would increase efficiency
- Another linked-list approach: a circular list
  - Let rear node point back to head node

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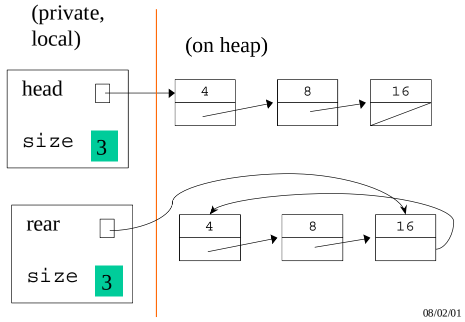
Conventional vs. Circular



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Array Implementation

- Choices for implementation
  - Array-based
  - Linked list
  - Exisiting Vector ADT implementation
- Stack: nItems was enough
- Queue: need to keep track of front and rear separately
  - still need to recognize empty queue, full queue

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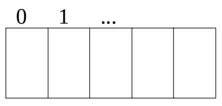
First Attempt

- int front, rear;
- Start at index 0, add new items left to right
- Insert: rear++
- Delete: front ++



This is a good start, but over time... what goes wrong?

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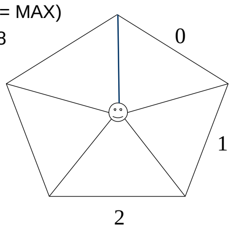
Wrap Around

- int size, front, rear;
- rear = (rear+1) % MAX; //on enqueue
- queueEmpty = (size == 0)
- queueFull = (size == MAX)
- Textbook p.317-318



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Computers and Simulation

- Computer programs are often used to “simulate” some aspect of the real world
  - Movement of people and things
  - Economic trends
  - Weather forecasting
  - Physical, chemical, industrial processes
- Why?
  - Cheaper, safer, more humane
  - But how accurate?

Simulation of a Bank

- People arrive and get in line for a teller
- When a teller is free, person at the head of the line gets served
  - Sounds like a queue is the right data model
- A bank might have different kinds of “tellers” (commercial tellers, loan officers, etc)
  - different queues for each one
- See textbook pp.324-334

Queues and Simulations

- Queues are often useful in simulations
  - because queues occur in the real world
- Common considerations
  - Time between arrival
  - Service time
  - Number of servers
- Often want to investigate/predict
  - Time spend waiting in queue
  - Effect of more/fewer servers
  - Effect of different arrival rates

Simulation vs Calculation

- Business question: *should the bank hire an additional teller?*
- Take a simplified situation:
  - People arrive on average one per minute
  - Each person spends on average one minute with the teller
  - Might be passed on historical statistics
- By calculation: each person waits on average one minute

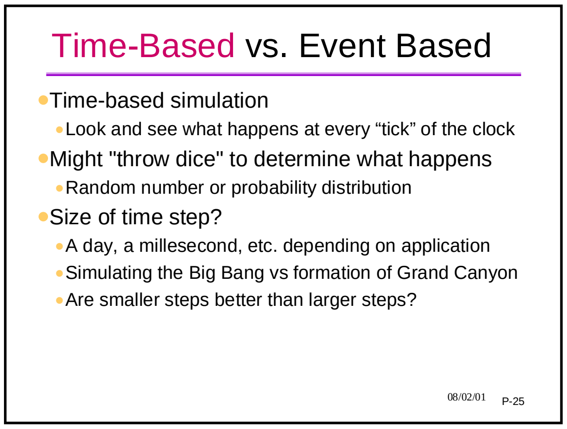
Would simulation give a different picture?

Airport 2001

- Planes approach the airport
- Wait for a controller
- Are assigned one of three runways
- Land and clear the runway
- What happens with:
  - more/fewer/differently scheduled planes?
  - more/fewer controllers?
  - another runway?
  - etc.
- What would computer model look like?

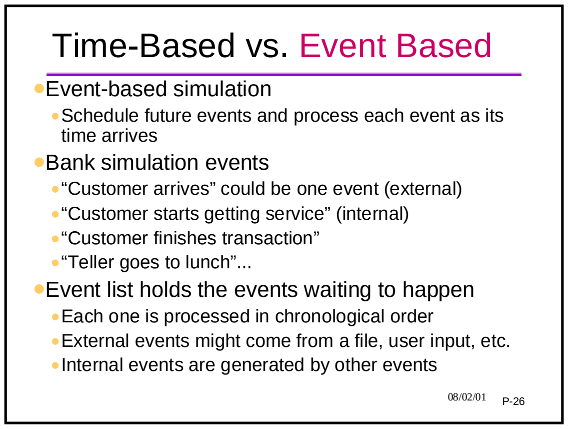
Simulations in Science

- Classical physics: describe the physical world with (differential) equations
  - Problem: too many interactions, equations too numerous and complex to solve exactly
- Alternative: build a model to simulate the operation
- Zillions of applications in physics, weather, astronomy, chemistry, biology, ecology, economics, etc. etc.
- Ideal model would allow safe virtual experiments and dependable conclusions



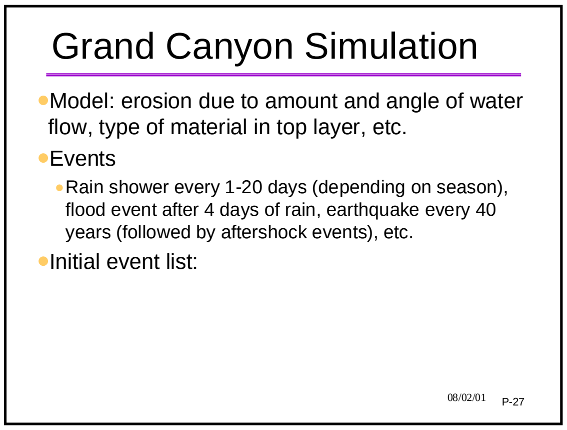
Time-Based vs. Event Based

- Time-based simulation
  - Look and see what happens at every “tick” of the clock
- Might "throw dice" to determine what happens
  - Random number or probability distribution
- Size of time step?
  - A day, a millesecond, etc. depending on application
  - Simulating the Big Bang vs formation of Grand Canyon
  - Are smaller steps better than larger steps?



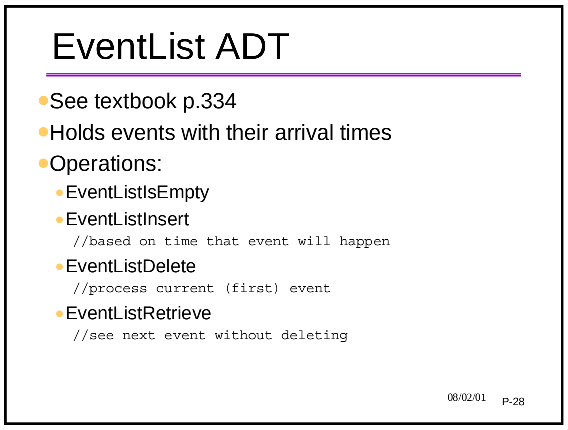
Time-Based vs. Event Based

- Event-based simulation
  - Schedule future events and process each event as its time arrives
- Bank simulation events
  - “Customer arrives” could be one event (external)
  - “Customer starts getting service” (internal)
  - “Customer finishes transaction”
  - “Teller goes to lunch”...
- Event list holds the events waiting to happen
  - Each one is processed in chronological order
  - External events might come from a file, user input, etc.
  - Internal events are generated by other events



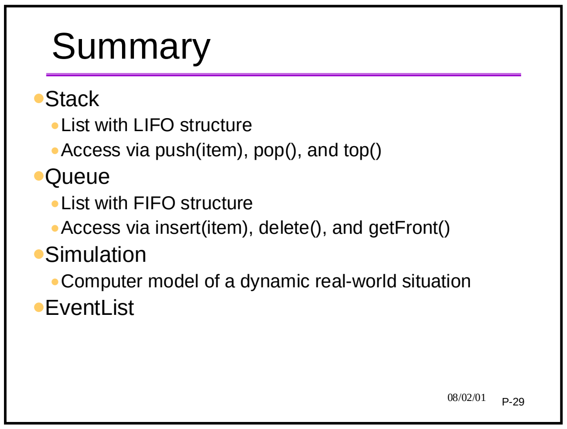
Grand Canyon Simulation

- Model: erosion due to amount and angle of water flow, type of material in top layer, etc.
- Events
  - Rain shower every 1-20 days (depending on season), flood event after 4 days of rain, earthquake every 40 years (followed by aftershock events), etc.
- Initial event list:



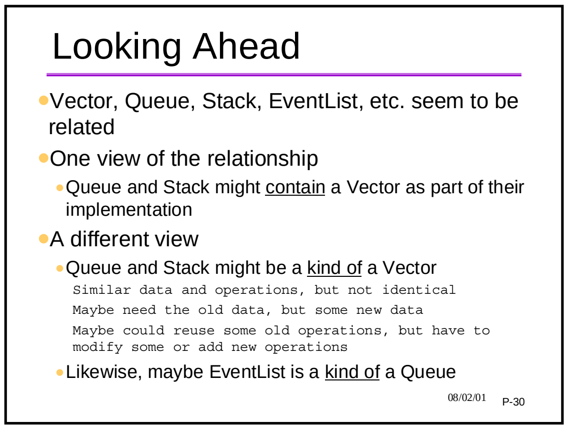
EventList ADT

- See textbook p.334
- Holds events with their arrival times
- Operations:
  - EventListIsEmpty
  - EventListInsert
    `//based on time that event will happen`
  - EventListDelete
    `//process current (first) event`
  - EventListRetrieve
    `//see next event without deleting`



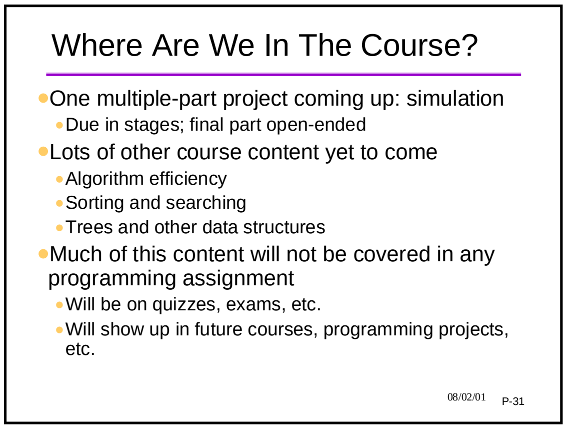
Summary

- Stack
  - List with LIFO structure
  - Access via push(item), pop(), and top()
- Queue
  - List with FIFO structure
  - Access via insert(item), delete(), and getFront()
- Simulation
  - Computer model of a dynamic real-world situation
- EventList



Looking Ahead

- Vector, Queue, Stack, EventList, etc. seem to be related
- One view of the relationship
  - Queue and Stack might contain a Vector as part of their implementation
- A different view
  - Queue and Stack might be a kind of a Vector
    ```
    Similar data and operations, but not identical
    Maybe need the old data, but some new data
    Maybe could reuse some old operations, but have to
    modify some or add new operations
    ```
  - Likewise, maybe EventList is a kind of a Queue



Where Are We In The Course?

- One multiple-part project coming up: simulation
  - Due in stages; final part open-ended
- Lots of other course content yet to come
  - Algorithm efficiency
  - Sorting and searching
  - Trees and other data structures
- Much of this content will not be covered in any programming assignment
  - Will be on quizzes, exams, etc.
  - Will show up in future courses, programming projects, etc.

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