

Topic 16

Queues

"FISH queue: n.

[acronym, by analogy with FIFO (First In, First Out)] 'First In, Still Here'. A joking way of pointing out that processing of a particular sequence of events or requests has stopped dead. Also FISH mode and FISHnet; the latter may be applied to any network that is running really slowly or exhibiting extreme flakiness."

-The Jargon File 4.4.7

Queues

- ▶ A sharp tool, like stacks
- ▶ A line
 - In England people don't "get in line" they "queue up".



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2

Queue Properties

- ▶ Queues are a first in first out data structure
 - FIFO (or LILO, but I guess that sounds a bit silly)
- ▶ Add items to the end of the queue
- ▶ Access and remove from the front
 - Access to the element that has been in the structure the **longest** amount of time
- ▶ Used extensively in operating systems
 - Queues of processes, I/O requests, and much more



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3

Queues in Operating Systems

- ▶ On a computer with N cores on the CPU, but more than N processes, how many processes can actually be executing at one time?
- ▶ One job of OS, schedule the processes for the CPU

Process Name	Status	% CPU	Nice	ID	Memory
at-spi-registryd	Sleeping	0	0	3683	2.4 MB
at-spi-activation-server	Sleeping	0	0	3158	332.0 KIB
bt-applet	Sleeping	0	0	3179	212.0 KIB
clock-applet	Sleeping	0	0	3241	676.0 KIB
dbus-daemon	Sleeping	0	0	3118	164.0 KIB
dbus-launch	Sleeping	0	0	3120	0 bytes
eggcup	Sleeping	0	0	3165	1.6 MB
esdc	Sleeping	0	0	3200	44.0 KIB
Firefox	Sleeping	0	0	15110	0 bytes
Firefox-bin	Sleeping	0	0	15126	143.5 MB
gdm_server	Sleeping	0	0	3220	156.0 KIB
gconfd-2	Sleeping	0	0	3126	504.0 KIB
gedit	Sleeping	0	0	1464	6.9 MB

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Process ID	Process Name	User	% CPU	# Threads	Real Memory	VSIZE
361	Finder	steve	0.00	4	21.05 MB	238.26 MB
366	Safari	steve	0.00	6	23.53 MB	252.85 MB
346	loginwindow	steve	0.00	2	3.80 MB	185.66 MB
367	iTunes	steve	4.00	10	22.03 MB	239.66 MB
371	Activity Monitor	steve	2.80	2	20.11 MB	246.64 MB
368	Photo	steve	0.00	3	33.39 MB	231.90 MB
374	Terminal	steve	0.00	4	12.98 MB	244.08 MB
360	SystemUIServer	steve	0.00	2	5.35 MB	227.74 MB
359	Dock	steve	0.00	2	6.43 MB	200.11 MB

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4

Queue operations

- ▶ `void enqueue(E item)`
 - a.k.a. `add(E item)`
- ▶ `E front()`
 - a.k.a. `E peek()`
- ▶ `E dequeue()`
 - a.k.a. `E remove()`
- ▶ `boolean isEmpty()`
- ▶ Specify methods in an interface, allow multiple implementations.

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5

Queue interface, version 1

```
public interface Queue314<E> {  
    //place item at back of this queue  
    public void enqueue(E item);  
  
    //access item at front of this queue  
    //pre: !isEmpty()  
    public E front();  
  
    //remove item at front of this queue  
    //pre: !isEmpty()  
    public E dequeue();  
  
    public boolean isEmpty();  
  
}
```

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6

Implementing a Queue

- ▶ Given the internal storage container and choice for front and back of queue what are the Big O of the queue operations?

	ArrayList	LinkedList (Singly Linked)	LinkedList (Doubly Linked)
enqueue			
front			
dequeue			
isEmpty			

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7

Clicker 1

- ▶ If implementing a queue with a singly linked list with references to the first and last nodes (head and tail) which end of the list should be the front of the queue in order to have all queue operations $O(1)$?
 - A. The front of the list should be the front of the queue.
 - B. The back of the list should be the front of the queue.
 - C. Either end will work to make all ops $O(1)$.
 - D. Neither end will allow all ops to be $O(1)$.

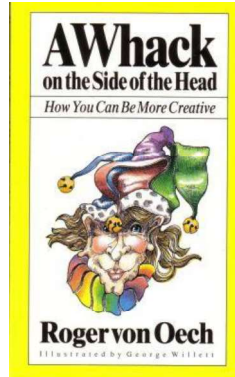
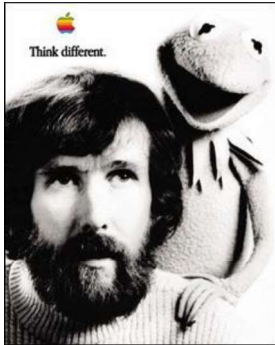
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Alternate Implementation

- ▶ How about implementing a Queue with a native array?
 - Seems like a step backwards



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Application of Queues

- ▶ Radix Sort
 - radix is a synonym for *base*. base 10, base 2
- ▶ Multi pass sorting algorithm that **only** looks at individual digits during each pass
- ▶ Use queues as *buckets* to store elements
- ▶ Create an array of 10 queues
- ▶ Starting with the least significant digit place value in queue that matches digit
- ▶ empty queues back into array
- ▶ repeat, moving to next least significant digit

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10

Radix Sort in Action: 1s place

- ▶ original values in array
9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12
- ▶ Look at ones place
9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12
- ▶ Array of Queues (all empty initially):

0	5
1	6
2	7
3	8
4	9

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11

Radix Sort in Action: 1s

- ▶ original values in array
9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12
- ▶ Look at ones place
9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12
- ▶ Queues:

0	<u>70</u> , <u>40</u>	5
1		6 <u>86</u>
2	<u>12</u> , <u>252</u> , <u>12</u>	7 <u>37</u> , <u>7</u>
3	<u>113</u> , <u>93</u>	8
4		9 <u>9</u> , <u>79</u>

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Radix Sort in Action: 10s

- ▶ Empty queues in order from 0 to 9 back into array

70, 40, 12, 252, 12, 113, 93, 86, 37, 7, 9, 79

- ▶ Now look at 10's place

70, 40, 12, 252, 12, 113, 93, 86, 37, 7, 9, 79

- ▶ Queues:

0	<u>7</u> , <u>9</u>	5	<u>2</u> <u>5</u> <u>2</u>
1	<u>1</u> 2, <u>1</u> 2, <u>1</u> 1 <u>3</u>	6	
2		7	<u>7</u> 0, <u>7</u> 9
3	<u>3</u> 7	8	<u>8</u> 6
4	<u>4</u> 0	9	<u>9</u> 3

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13

Radix Sort in Action: 100s

- ▶ Empty queues in order from 0 to 9 back into array

7, 9, 12, 12, 113, 37, 40, 252, 70, 79, 86, 93

- ▶ Now look at 100's place

7, 9, 12, 12, 113, 37, 40, 252, 70, 79, 86, 93

- ▶ Queues:

0	<u>7</u> , <u>9</u> , <u>1</u> 2, <u>1</u> 2, <u>3</u> 7, <u>4</u> 0, <u>7</u> 0, <u>7</u> 9, <u>8</u> 6, <u>9</u> 3	5
1	<u>1</u> 1 <u>3</u>	6
2	<u>2</u> 5 <u>2</u>	7
3		8
4		9

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14

Radix Sort in Action: Final Step

- ▶ Empty queues in order from 0 to 9 back into array

7, 9, 12, 12, 40, 70, 79, 86, 93, 113, 252

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15

Radix Sort Code

```
public static void sort(int[] list){
    ArrayList<Queue<Integer>> queues = new ArrayList<Queue<Integer>>();
    for(int i = 0; i < 10; i++){
        queues.add( new LinkedList<Integer>() );
    }
    int passes = numDigits(list[0]); // helper method
    // or int passes = (int) Math.log10(list[0]);
    for(int i = 1; i < list.length; i++){
        int temp = numDigits(list[i]);
        if( temp > passes )
            passes = temp;
    }
    for(int i = 0; i < passes; i++){
        for(int j = 0; j < list.length; j++){
            queues.get( valueOfDigit( list[j], i ) ).add(list[j]);
        }
        int pos = 0;
        for(Queue<Integer> q : queues){
            while(!q.isEmpty())
                list[pos++] = q.remove();
        }
    }
}
```

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16