Priority Queue ADT

Revised based on textbook author's notes.

Priority Queues

- Some applications require the use of a queue in which items are assigned a priority.
  - higher priority items are dequeued first.
  - items with equal priority still follow FIFO.

Some Applications

- Operating systems such as Linux use priority queues to manage their jobs (try e.g., the top command)
- Simulations use priority queues to manage events to be simulated
- All other FIFO queues, e.g., online shopping queues are special cases of priority queue, that is, time is the priority

The Priority Queue ADT

- A *priority queue* is a queue in which each item is assigned a priority and items with a higher priority are removed before those with lower priority.
  - Integer values are used for the priorities.
  - Smaller integers have a higher priority.

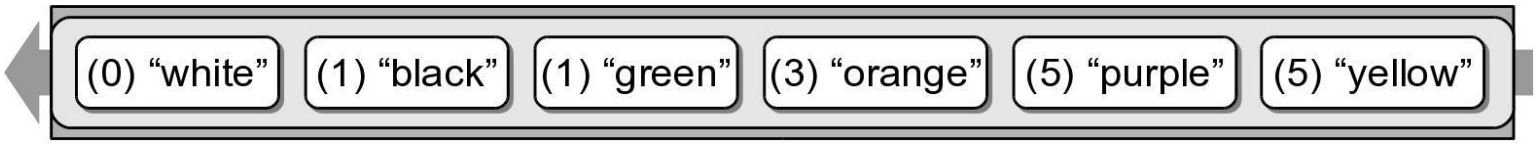
The Operations

- PriorityQueue()
- is_empty()
- len()
- enqueue(item, priority)
- dequeue()
- peek()

Priority Queue Example

- Consider the following code segment:

```
Q = PriorityQueue( 6 )
Q.enqueue( “purple”, 5 )
Q.enqueue( “black”, 1 )
Q.enqueue( “orange”, 3 )
Q.enqueue( “white”, 0 )
Q.enqueue( “green”, 1 )
Q.enqueue( “yellow”, 5 )
```



Priority Queue Implementation

- How should the ADT be implemented. We must consider:
  - A priority must be associated with each item in the queue.
  - The next item dequeued is the item with the highest priority.
  - If multiple items have the same priority, those must be dequeued in a FIFO order.

Priority Queue Implementation

- There can be many different implementations, we'll consider three here
  - Textbook approach
  - Linked list
  - Bounded array with linked lists

1. Textbook approach

- The priority queue is implemented as a Python list
- The enqueue operation puts the item at the end of the queue (as in our FIFO queue)
- The dequeue operation takes the item with the highest priority off the queue (note: the item could be anywhere in the queue!)

Queue operations

```
def enqueue( self, item, priority ):
  """Adds the given item to the queue."""
  # Create a new instance of the storage class and append it to the list.
  entry = _PriorityQEntry( item, priority )
  self._qlist.append( entry )

def dequeue( self ) :
  """ Removes and returns the first item in the queue."""
  assert not self.is_empty(), "Cannot dequeue from an empty queue."

  # Find the entry with the highest priority
  top = self.find_top_priority()

  # Remove the entry with the highest priority and return the item.
  entry = self._qlist.pop( top )
  return entry

def peek( self ):
  """Return the value of the top priority without removing it"""
  assert not self.is_empty(), "Cannot peek from an empty queue."

  top = self.find_top_priority()
  return self._qlist[top].item

def find_top_priority( self ):
  """Find the entry with the highest priority."""
  highest   = self._qlist[0].priority
  high_index = 0
  for i in range( len( self ) ) :
    # See if the ith entry contains a higher priority (smaller integer).
    if self._qlist[i].priority < highest :
      highest = self._qlist[i].priority
      high_index = i

  return high_index
```

Details of find_top_priority()

Basically it is the same process of finding a minimum in a list.

```
def find_top_priority(self):
        highest_index = 0
        highest = self._qlist[highest_index].priority
        for i in range(len(self)):
            if highest > self._qlist[i].priority:    # smaller value has higher priority
                highest_index = i
                highest = self._qlist[i].priority
        return highest_index
```

Try the program testpriorityqueue.py

Complexity of operations

What is the complexity for dequeue?

O(n)

What is the complexity for enqueue?

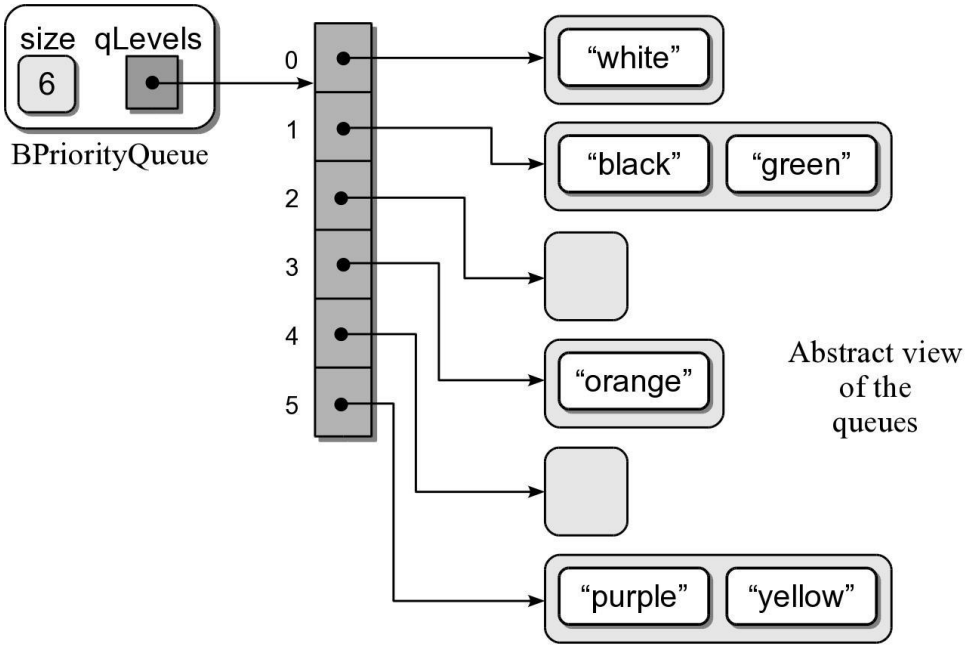
O(1)

2. Bounded Priority Queue

- A bounded priority queue has a fixe set of priorities
- We use an array to represent the set of priorities, each array element maintains a queue of the items with the same priority

Bounded Priority Queue

- The following example shows a bounded priority queue with six levels



Bounded Priority Q Implementation

bpriorityq.py

```
from array204 import Array
from llistqueue import Queue

class BPriorityQueue :
  def __init__( self, num_levels = 6 ):
    self._qsize = 0
    self._qlevels = Array( num_levels )
    for i in range( num_levels ) :
      self._qlevels[i] = Queue()

  def is_empty( self ):
    return len( self ) == 0

  def __len__( self ):
    return len( self._qsize )

# ...
```

Bounded Priority Q Implementation

bpriorityq.py

```
class BPriorityQueue :
# ...
  def enqueue( self, item, priority ):
    assert priority >= 0 and priority < len(self._qlevels), \
           "Invalid priority level."
    self._qlevels[priority].enqueue( item )

  def dequeue( self ) :
    # Make sure the queue is not empty.
    assert not self.is_empty(), "Cannot dequeue from an empty queue."

    # Find the first non-empty queue.
    top_index = self.find_top_priority_queue()

    # We know the queue is not empty, so dequeue from the ith queue.
    return self._qlevels[top_index].dequeue()
```

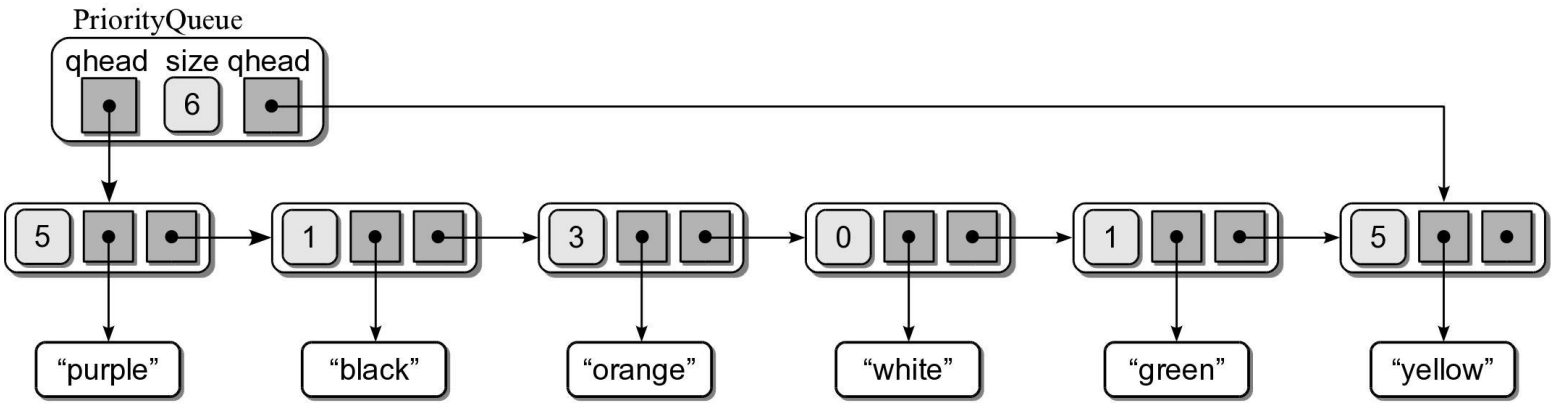
Bounded Priority Q Implementation

bpriorityq.py

```
class BPriorityQueue :
# ...
   def find_top_priority_queue(self):
      # find the first non-empty queue, a.k.a. highest priority
      i = 0
      p = len(self._qlevels)
      while i < p and self._qlevels[i].is_empty() :
         i += 1
      return i
```

Unbounded Priority Q: Linked List

- We can use a singly linked list:
  - Head and tail references.
  - Append new entries to the end.



Priority Queue Analysis

- The worst case analysis for the two implementations.

Queue Operation	Python List	Linked List
q = PriorityQueue()	O(1)	O(1)
len(q)	O(1)	O(1)
q.is_empty()	O(1)	O(1)
q.enqueue(x)	O(n)	O(1)
x = q.dequeue()	O(n)	O(n)

Implement enqueue()

- Your task is to implement the enqueue() method for a linked list based queue in which other necessary methods have been implemented