14.1 Bubble sort

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Bubble sort is a sorting algorithm that iterates through a list, comparing and swapping adjacent elements if the second element is less than the first element. Bubble sort uses nested loops. Given a list with N elements, the outer i-loop iterates N - 1 times. Each iteration moves the largest element into sorted position. The inner j-loop iterates through all adjacent pairs, comparing and swapping adjacent elements as needed, except for the last i pairs that are already in the correct position.

Because of the nested loops, bubble sort has a runtime of O( ). Bubble sort is often considered impractical for real-world use because many faster sorting algorithms exist.

Figure 14.1.1: Bubble sort algorithm.

```
BubbleSort(numbers, numbersSize) {
   for (i = 0; i < numbersSize - 1; i++) {
      for (j = 0; j < numbersSize - i - 1;
j++) {
         if (numbers[j] > numbers[j+1]) {
            temp = numbers[j]
            numbers[j] = numbers[j + 1]
            numbers[j + 1] = temp
         }
      }
   }
}
```

PARTICIPATION ACTIVITY 14.1.1: Bubble sort.

1) Bubble sort uses a single loop to sort the list.

   - True
   - False

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2) Bubble sort only swaps adjacent elements.

   - True
   - False

3) Bubble sort's best and worst runtime complexity is O( ).

- True
- False

14.2 Quickselect

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Quickselect is an algorithm that selects the smallest element in a list. Ex: Running quickselect on the list (15, 73, 5, 88, 9) with k = 0, returns the smallest element in the list, or 5.

For a list with N elements, quickselect uses quicksort's partition function to partition the list into a low partition containing the X smallest elements and a high partition containing the N-X largest elements. The smallest element is in the low partition if k is ≤ the last index in the low partition, and in the high partition otherwise. Quickselect is recursively called on the partition that contains the element. When a partition of size 1 is encountered, quickselect has found the smallest element.

Quickselect partially sorts the list when selecting the smallest element.

The best case and average runtime complexity of quickselect are both O( ). In the worst case, quickselect may sort the entire list, resulting in a runtime of O( ).

Figure 14.2.1: Quickselect algorithm.

```
// Selects kth smallest element, where k is 0-based
Quickselect(numbers, first, last, k) {
   if (first >= last)
      return numbers[first]

   lowLastIndex = Partition(numbers, first, last)

   if (k <= lowLastIndex)
      return Quickselect(numbers, first, lowLastIndex,
k)
   return Quickselect(numbers, lowLastIndex + 1, last,
k)
}
```

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PARTICIPATION ACTIVITY 14.2.1: Quickselect.

1) Calling quickselect with argument k equal to 1 returns the smallest element in the list.

- True
- False

2) The following function produces the same result as quickselect, albeit with a different runtime complexity.

```
Quickselect(numbers, first,
last, k) {
   Quicksort(numbers, first,
last)
   return numbers[k]
}
```

- True
- False

3) Given k = 4, if the quickselect call `Partition(numbers, 0, 10)` returns 4, then the element being selected is in the low partition.

- True
- False

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CHALLENGE ACTIVITY 14.2.1: Quickselect.

502696.2096894.qx3zqy7

Start

What is returned when running quickselect on [88, 60, 16, 38, 65, 52] with k = 0?

Ex: 10

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1 2 3

Check Next

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14.3 Python: Quickselect

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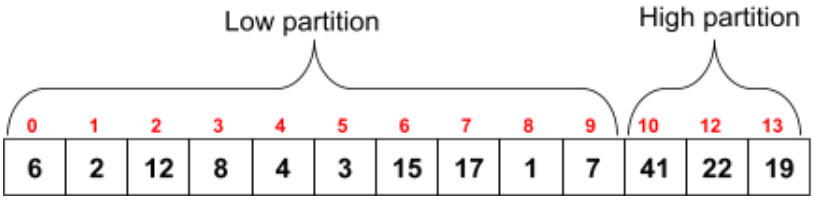
Python: Quickselect

The Quickselect algorithm is used to find the smallest item in a list. The quickselect() function has some similarities to the quicksort() function: both functions are recursive, and both functions use the partition() function to rearrange a portion of the input list into sections that are less than or greater than a selected pivot. Unlike quicksort(), however, quickselect() is recursively applied to only *one* of the partitions.

Figure 14.3.1: A list after being partitioned into low and high partitions.



The example above shows a list after the partition() function is called. To find the 7th smallest value in the list (that is,), the value must appear in the low partition, because the low partition holds the 10 smallest values. Similarly, the 11th smallest value has to be one of the three values in the high partition. The quickselect() function partitions the list and then recursively calls quickselect() on whichever partition the element is in. The recursion ends when the current partition has only one element, and that element has to be the element that is being searched for.

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Figure 14.3.2: The quickselect() function.

```
def quickselect(numbers, start_index, end_index, k):
    if start_index >= end_index:
        return numbers[start_index]

    low_last_index = partition(numbers, start_index, end_index)
    if k <= low_last_index:
        return quickselect(numbers, start_index,
low_last_index, k)

    return quickselect(numbers, low_last_index + 1, end_index,
k)
```

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Each recursive call reduces the size of the partition being examined. If partition() partitions the list more-or-less in half, then quickselect() performs extremely well. In the average and best cases, quickselect() runs in time. However, if the partitions are consistently uneven, quickselect() can end up using partition() to sort the entire list, taking time. In practice, with reasonably random-appearing data, the algorithm is very efficient.

PARTICIPATION ACTIVITY 14.3.1: quickselect() function.

Which action will the quickselect() method take for each condition?

1) numbers: [6, 2, 12, 8, 4, 3, 19, 17, 22, 41, 7, 1, 15]
   start_index: 0
   end_index: 12
   k: 5
   The first action is:

   - return numbers[5]
   - partition(numbers, 0, 12)
   - partition(numbers, 5, 12)
   - quickselect(numbers, 0, 5, 5)
   - quickselect(numbers, 5, 12, 5)

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2) numbers: [1, 2, 3, 4, 8, 12, 7, 6, 17, 15, 41, 22, 19]
start_index: 4
end_index: 7
k: 5
low_last_index: 6
After partition(numbers, 4, 7) returns:

- quickselect(numbers, 4, 7, 5)
- quickselect(numbers, 4, 6, 5)
- quickselect(numbers, 6, 7, 5)

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3) numbers: [6, 2, 12, 8, 4, 3, 15, 17, 1, 7, 41, 22, 19]
start_index: 0
end_index: 9
k: 5
low_last_index: 3
After partition(numbers, 0, 9) returns:

- quickselect(numbers, 0, 3, 5)
- quickselect(numbers, 0, 3, 3)
- quickselect(numbers, 4, 9, 5)

zyDE 14.3.1: Working with quickselect().

The following program uses quickselect() to find the smallest item. The value of k is t from user input.

Run the program with some different values for k. Observe the following:

- The quickselect() function does, in fact, always return the smallest item. The so list is shown at the end so the value of the smallest item can be confirmed.
- The list becomes *partially* sorted after calling quickselect(). Which partitions becom sorted depend on the value of k. Try different values for k to see this: k=3, k=7, k=11

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main.py **Load default templat**

```
def partition(numbers, start_index, end_index):
    # select the middle value as the pivot.
    midpoint = start_index + (end_index - start_index) // 2
    pivot = numbers[midpoint]

    # "low" and "high" start at the ends of the current list partitior
    # and move towards each other.
```

```
    low = start_index
    high = end_index

    done = False
    while not done:
        # Increment low while numbers[low] < pivot
        while numbers[low] < pivot:
            low = low + 1
```

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5

Run

14.4 Bucket sort

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Bucket sort is a numerical sorting algorithm that distributes numbers into buckets, sorts each bucket with an additional sorting algorithm, and then concatenates buckets together to build the sorted result. A ***bucket*** is a container for numerical values in a specific range. Ex: All numbers in the range 0 to 49 may be stored in a bucket representing this range. Bucket sort is designed for arrays with non-negative numbers.

Bucket sort first creates a list of buckets, each representing a range of numerical values. Collectively, the buckets represent the range from 0 to the maximum value in the array. For buckets and a maximum value of , each bucket represents —— values. Ex: For 10 buckets and a maximum value of 49, each bucket represents a range of —— = 5 values; the first bucket will hold values ranging from 0 to 4, the second bucket 5 to 9, and so on. Each array element is placed in the appropriate bucket. The bucket index is calculated as —— . Then, each bucket is sorted with an additional sorting algorithm. Lastly, all buckets are concatenated together in order, and copied to the original array.

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Figure 14.4.1: Bucket sort algorithm.

```
BucketSort(numbers, numbersSize, bucketCount) {
   if (numbersSize < 1)
      return

   buckets = Create list of bucketCount buckets

   // Find the maximum value
   maxValue = numbers[0]
   for (i = 1; i < numbersSize; i++) {
      if (numbers[i] > maxValue)
         maxValue = numbers[i]
   }

   // Put each number in a bucket
   for each (number in numbers) {
      index = floor(number * bucketCount / (maxValue +
1))
      Append number to buckets[index]
   }

   // Sort each bucket
   for each (bucket in buckets)
      Sort(bucket)

   // Combine all buckets back into numbers list
   result = Concatenate all buckets together
   Copy result to numbers
}
```

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PARTICIPATION ACTIVITY 14.4.1: Bucket sort.

Suppose BucketSort is called to sort the list (71, 22, 99, 7, 14), using 5 buckets.

1) 71 and 99 will be placed into the same bucket.
   - True
   - False

2) No bucket will have more than 1 number.
   - True
   - False

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3) If 10 buckets were used instead of 5, no bucket would have more than 1 number.
   - True
   - False

Bucket sort terminology

The term "bucket sort" is sometimes used to refer to a category of sorting algorithms, instead of a specific sorting algorithm. When used as a categorical term, bucket sort refers to a sorting algorithm that places numbers into buckets based on some common attribute, and then combines bucket contents to produce a sorted array.

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14.5 List data structure

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A common approach for implementing a linked list is using two data structures:

1. List data structure: A ***list data structure*** is a data structure containing the list's head and tail, and may also include additional information, such as the list's size.
2. List node data structure: The list node data structure maintains the data for each list element, including the element's data and pointers to the other list element.

A list data structure is not required to implement a linked list, but offers a convenient way to store the list's head and tail. When using a list data structure, functions that operate on a list can use a single parameter for the list's data structure to manage the list.

A linked list can also be implemented without using a list data structure, which minimally requires using separate list node pointer variables to keep track of the list's head.

PARTICIPATION ACTIVITY 14.5.1: Linked lists can be stored with or without a list data structure.

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undefined

Animation captions:

1. A linked list can be maintained without a list data structure, but a pointer to the head and tail of the list must be stored elsewhere, often as local variables.
2. A list data structure stores both the head and tail pointers in one object.

PARTICIPATION ACTIVITY 14.5.2: Linked list data structure.

1) A linked list must have a list data structure.
   - True
   - False

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2) A list data structure can have additional information besides the head and tail pointers.
   - True
   - False

3) A linked list has O(n) space complexity, whether a list data structure is used or not.
   - True
   - False

14.6 Circular lists

This section has been set as optional by your instructor.

A ***circular linked list*** is a linked list where the tail node's next pointer points to the head of the list, instead of null. A circular linked list can be used to represent repeating processes. Ex: Ocean water evaporates, forms clouds, rains down on land, and flows through rivers back into the ocean. The head of a circular linked list is often referred to as the *start* node.

A traversal through a circular linked list is similar to traversal through a standard linked list, but must terminate after reaching the head node a second time, as opposed to terminating when reaching null.

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PARTICIPATION ACTIVITY 14.6.1: Circular list structure and traversal.

Animation content:

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Animation captions:

1. In a circular linked list, the tail node's next pointer points to the head node.
2. In a circular doubly-linked list, the head node's previous pointer points to the tail node.
3. Instead of stopping when the "current" pointer is null, traversal through a circular list stops when current comes back to the head node.

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PARTICIPATION ACTIVITY 14.6.2: Circular list concepts.

1) Only a doubly-linked list can be circular.

- ○ True
- ○ False

2) In a circular doubly-linked list with at least 2 nodes, where does the head node's previous pointer point to?

- ○ List head
- ○ List tail
- ○ null

3) In a circular linked list with at least 2 nodes, where does the tail node's next pointer point to?

- ○ List head
- ○ List tail
- ○ null

4) In a circular linked list with 1 node, the tail node's next pointer points to the tail.

- ○ True
- ○ False

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5) The following code can be used to traverse a circular, doubly-linked list in reverse order.

```
CircularListTraverseReverse(tail)
{
   if (tail is not null) {
      current = tail
      do {
         visit current
         current =
current→previous
      } while (current != tail)
   }
}
```

- True
- False

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