Searching & Sorting

Week 11

Gaddis: 8, 19.6,19.8

CS 5301
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Definitions of Search and Sort

- Search: find a given item in a list, return the index to the item, or -1 if not found.
- Sort: rearrange the items in an array into some order (smallest to biggest, alphabetical order, etc.).
- There are various methods (algorithms) for carrying out these common tasks.

Linear Search

- Very simple method.
- Compare first element to target value,
  if not found then compare second element to target value . . .
- Repeat until:
  target value is found (return its index) or
  we run out of items (return -1).

Linear Search in C++

```
int searchList (int list[], int size, int value) {

  int index=0;           //index to process the array
  int position = -1;     //position of target
  bool found = false;    //flag, true when target is found

  while (index < size && !found)
  {
    if (list[index] == value)  //found the target!
    {
      found = true;            //set the flag
      position = index;        //record which item
    }
    index++;                   //increment loop index
  }
  return position;
}
```

Linear Search in C++

simplified

```
int searchList (int list[], int size, int value) {

  for (int i=0; i<size; i++)
  {
    if (list[i] == value)
       return i;
  }
  return -1;
}
```


Other forms of Linear Search

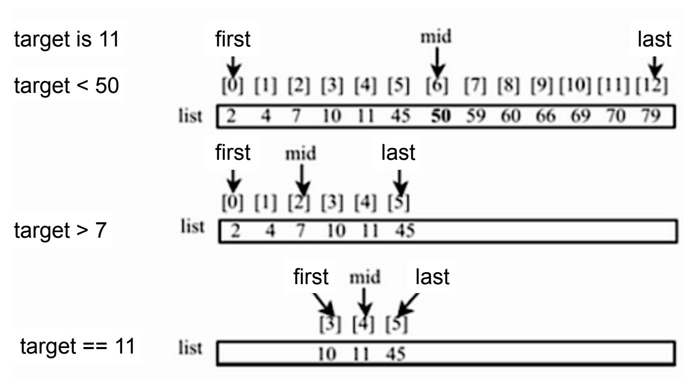
- Recursive linear search over arrays
  - See Lab 10, exercise #1: isMember function
- Linear search over linked list
  - A good exercise (Gaddis ch 17 Prog Challenge #5)
- Recursive linear search over linked list
  - Another good exercise

Binary Search

- Works only for SORTED arrays
- Divide and conquer style algorithm
- Compare target value to middle element in list.
  - if equal, then return its index
  - if less than middle element, repeat the search in the first half of list
  - if greater than middle element, repeat the search in last half of list
- If current search list is narrowed down to 0 elements, return -1

Binary Search Algorithm

example



Binary Search in C++

iterative version

```
int binarySearch (int array[], int size, int target) {

  int first = 0,           //index to (current) first elem
      last = size – 1,     //index to (current) last elem
      middle,              //index of (current) middle elem
      position = -1;       //index of target value
  bool found = false;      //flag

  while (first <= last && !found) {

    middle = (first + last) /2;     //calculate midpoint

    if (array[middle] == target) {
      found = true;
      position = middle;
    } else if (target < array[middle]) {
      last = middle – 1;             //search lower half
    } else {
      first = middle + 1;            //search upper half
    }
  }
  return position;
}
```


Binary Search in C++

Recursive version

```
int binarySearchRec(int array[], int first, int last, int value)
{
    int middle; // Mid point of search

    if (first > last)            //check for empty list
        return -1;
    middle = (first + last)/2;   //compute middle index
    if (array[middle]==value)
        return middle;
    if (value < array[middle])    //recursion
        return binarySearchRec(array, first,middle-1, value);
    else
        return binarySearchRec(array, middle+1,last, value);
}

int binarySearch(int array[], int size, int value) {
    return binarySearchRec(array, 0, size-1, value);
}
```


What is sorting?

- Sort: rearrange the items in a list into ascending or descending order
  - numerical order
  - alphabetical order
  - etc.

55 112 78 14 20 179 42 67 190 7 101 1 122 170 8

1 7 8 14 20 42 55 67 78 101 112 122 170 179 190

Sorting algorithms

- Bubble sort
- Merge sort
- Quicksort

Bubble sort

- On each pass:
  - Compare first two elements. If the first is bigger, they exchange places (swap).
  - Compare second and third elements. If second is bigger, exchange them.
  - Repeat until last two elements of the list are compared.
- Repeat this process until a pass completes with no exchanges

Bubble sort

how does it work?

- At the end of the first pass, the largest element is moved to the end (it's bigger than all its neighbors)
- At the end of the second pass, the second largest element is moved to just before the last element.
- The back end (tail) of the list remains sorted.
- Each pass increases the size of the sorted portion.
- No exchanges implies each element is smaller than its next neighbor (so the list is sorted).

Bubble sort

Example

- 7 2 3 8 9 1 7 > 2, swap
- 2 7 3 8 9 1 7 > 3, swap
- 2 3 7 8 9 1 !(7 > 8), no swap
- 2 3 7 8 9 1 !(8 > 9), no swap
- 2 3 7 8 9 1 9 > 1, swap
- 2 3 7 8 1 9 finished pass 1, did 3 swaps

Note: largest element is in last position

Bubble sort

Example

- 2 3 7 8 1 9 2<3<7<8, no swap, !(8<1), swap
- 2 3 7 1 8 9 (8<9) no swap
- finished pass 2, did one swap

2 largest elements in last 2 positions

- 2 3 7 1 8 9 2<3<7, no swap, !(7<1), swap
- 2 3 1 7 8 9 7<8<9, no swap
- finished pass 3, did one swap

3 largest elements in last 3 positions

Bubble sort

Example

- 2 3 1 7 8 9 2<3, !(3<1) swap, 3<7<8<9
- 2 1 3 7 8 9
- finished pass 4, did one swap
- 2 1 3 7 8 9 !(2<1) swap, 2<3<7<8<9
- 1 2 3 7 8 9
- finished pass 5, did one swap
- 1 2 3 7 8 9 1<2<3<7<8<9, no swaps
- finished pass 6, no swaps, list is sorted!

Bubble sort: code

```
template<class ItemType>
void bubbleSort (ItemType a[], int size) {

    bool swapped;
    do {
        swapped = false;
        for (int i = 0; i < (size-1); i++) {
            if (a[i] > a[i+1]) {
                swap(a[i],a[i+1]);
                swapped = true;
            }
        }
    } while (swapped);
}
```


Merge sort

- Divide and conquer!
- 2 half-sized lists sorted recursively
- the algorithm:
  - if list size is 0 or 1, return (base case) otherwise:
  - recursively sort first half and then second half of list.
  - merge the two sorted halves into one sorted list.

Merge sort

Example

- **Recursively** divide list in half:
  - call mergeSort recursively on each one.

5 2 4 6 1 3 2 6

5 2 4 6 | 1 3 2 6

5 2 | 4 6 | 1 3 | 2 6

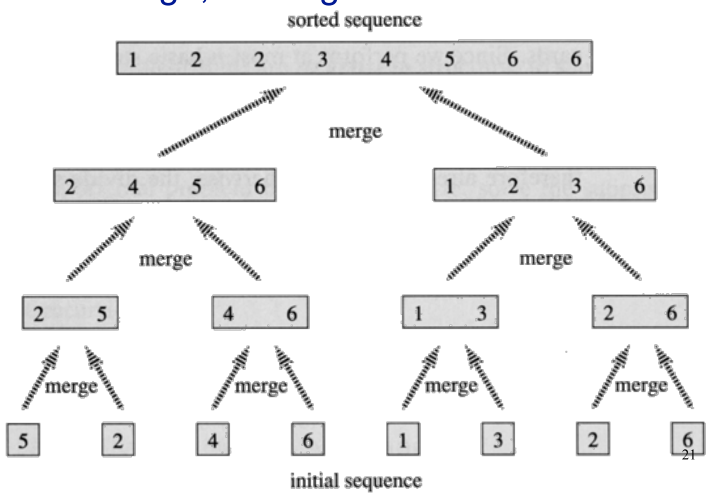
5 | 2 | 4 | 6 | 1 | 3 | 2 | 6

Each of these are sorted (base case length = 1)

Merge sort

Example

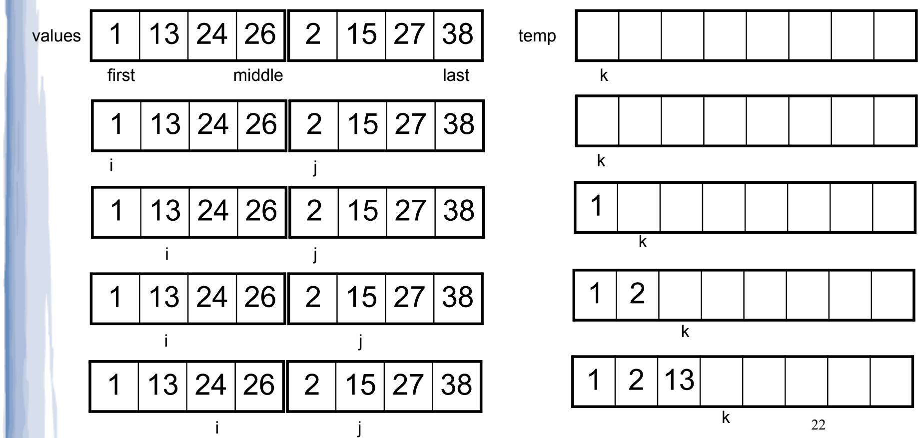
- Calls to merge, starting from the bottom:



Merge sort

Merging

- How to merge 2 (adjacent) lists:

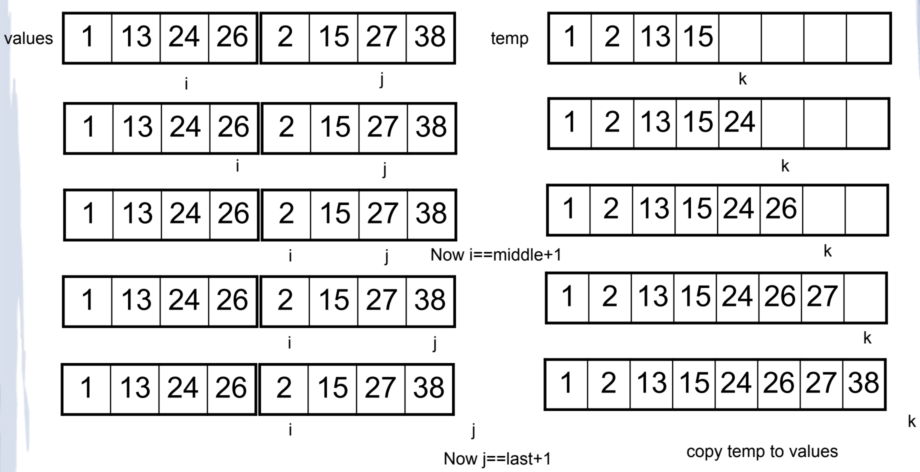


compare values[i] to values[j], copy smaller to temp[k]

Merge sort

Merging

- Continued:



Merge sort: code

```
void mergeSortRec (double values[], int first, int last) {
    if (first < last) {
        int middle = (first + last) / 2;

        mergeSortRec(values, first, middle);
        mergeSortRec(values, middle+1, last);

        merge(values, first, middle, last);
    }
}

void mergeSort (double values[], int size) {
    mergeSortRec(values, 0, size-1);
}
```

Merge sort: code: merge

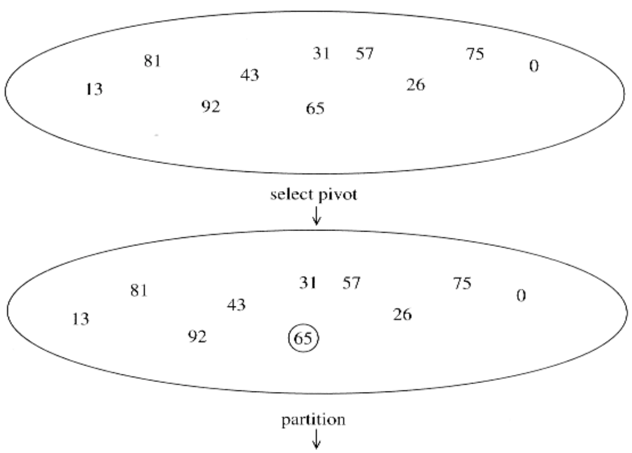
```
void merge(double values[], int first, int middle, int last) {
    double *tmp = new double[last-first+1];  //temporary array
    int i=first;        //index for left
    int j=middle+1;     //index for right
    int k=0;            //index for tmp

    while (i<=middle && j<=last)   //merge, compare next elem from each array
        if (values[i] < values[j])
            tmp[k++] = values[i++];
        else
            tmp[k++] = values[j++];

    while (i<=middle)           //merge remaining elements from left, if any
        tmp[k++] = values[i++];

    while (j<=last)             //merge remaining elements from right, if any
        tmp[k++] = values[j++];

    for (int i = first; i <=last; i++) //copy from tmp array back to values
        values[i] = tmp[i-first];
    delete [] tmp;                //deallocate temp array
}
```


Quick sort

- Another divide and conquer!
- 2 (hopefully) half-sized lists sorted recursively
- the algorithm:
  - If list size is 0 or 1, return. otherwise:
  - partition into two lists:
    - pick one element as the pivot
    - put all elements less than pivot in first half
    - put all elements greater than pivot in second half
  - recursively sort first half and then second half of list.

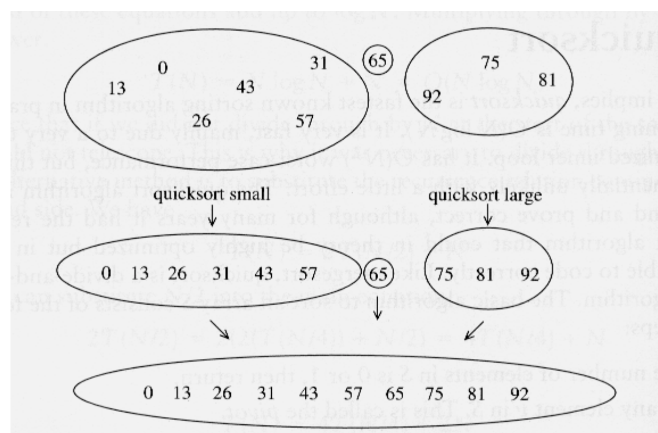
Quicksort

Example



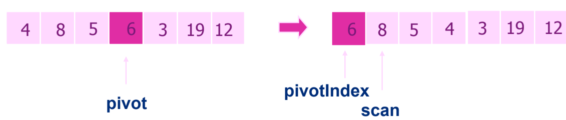
Quicksort

Example cont.



Quicksort: partitioning

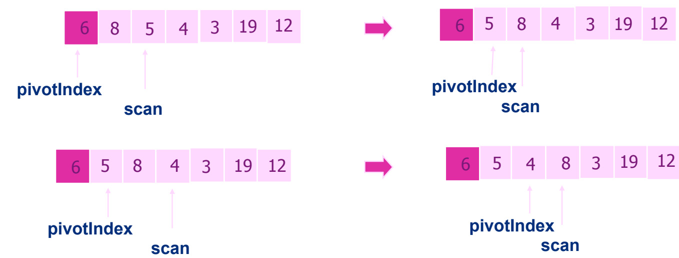
- Goal: partition a sub-array A [start...end] by rearranging the elements and returning the index of the pivot point p so that:
  - A[x]<=A[p] for x<p and A[x]>=A[p] for x>p
- the algorithm:
  - pick a pivot value and swap with start elem
  - let pivotIndex = start and scan = start +1



Quicksort: partitioning

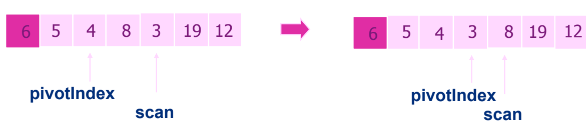
- use scan to iterate over the list elements
  - whenever set[scan] < the pivot value (6):
    a. increment pivotIndex and then
    b. swap set[pivotIndex] with set[scan].

This maintains:
A[x]<=A[pivotIndex] for x<=pivotIndex,
(All elements left of pivotIndex are <= 6)

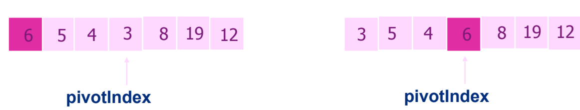


Quicksort: partitioning

- the algorithm (continued):



  - then, after the scan, swap start with pivotIndex, and return pivotIndex



Note: pivotIndex is not always the midpoint

Quicksort: code

```
void quickSort(int set[], int start, int end) {

  if (start < end)
   {
      // Get the pivot point.
      int pivotPoint = partition(set, start, end);
      // Sort the first sub list.
      quickSort(set, start, pivotPoint - 1);
      // Sort the second sub list.
      quickSort(set, pivotPoint + 1, end);
   }
}

void quickSort (int set[], int size) {
    quickSort(set, 0, size-1);
}
```

Quicksort: code

```
int partition(int set[], int start, int end)
{
   int mid = (start + end) / 2;  // locate the pivot value
   swap(set[start], set[mid]);
   int pivotIndex = start;
   int pivotValue = set[start];
   for (int scan = start + 1; scan <= end; scan++)
   {  // finds values less than pivotValue and
      // moves them to the left of the pivotIndex
      if (set[scan] < pivotValue)
      {
         pivotIndex++;
         swap(set[pivotIndex], set[scan]);
      }
   }
   swap(set[start], set[pivotIndex]);
   return pivotIndex;
}
```