(8-2) Arrays II
H&K Chapter 7

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Washington State University

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Array Searching (1)

- Lots of motivating problems
  - Find a name in the phone book
  - Amazon automated warehouse

    https://www.youtube.com/watch?v=Ox05Bks2Q3s
  - Others: https://www.youtube.com/watch?v=TvRbxGoJrUU

Graph is from: https://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/6880/Amazons-Robotic-Order-Fulfillment.aspx

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Array Searching (2)

- Sequential Search Algorithm
  - Solution strategy: search list sequentially but halt if not found

```
Get the value of target and the list of names N1, N2, . . . Ni
Set the value of num to 1
Set the value of found to false
While (num <= i) and (found = false)
  if target = Nnum
    set found to true
  else
    set num to num + 1
Endwhile
```

Pseudo code was also written on the white board in the class.

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Array Searching (3)

- C adaptation of sequential search

```
int sequential_search(int values[],int target, int num_values)
{
  int index, found;
  index = 0;
  found = 0; /* false */
  while (index < num_values && !found)
  {
          if (values[index] == target){found = 1;}
          else {index++;}
  }
  /* return index at which target was found */
  if (found){return (index);}
  else {return NOT_FOUND; /* #defined to -1 */}
}
```


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Array Searching (4)

Binary Search

Real life example: **https://www.youtube.com/watch?v=YgVNJ2v9IPA**

- *Input*: a list of n ***sorted*** values and a target value
- *Output*: True if target value exists in list and location of target value, false otherwise
- *Method*:
  - Set left to 1 and right to n
  - Set found to false
  - While found is false and left is less than or equal to right
    - Set mid to midpoint between left and right
    - If target = item at mid then set found to true
    - If target < item then set right to mid – 1
    - If target > item then set to left to mid + 1
  - If found = true then print "Target found at location mid"
  - Else print "Sorry, target value could not be found."

Steps were also drawn in the whiteboard during the class.

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Visualization of Binary Search (1)

Let's say we're searching for the value 33. Initially, we set L to 0, R to 26, and found to false:

L																												R
12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26		

Since found is false and L <= R, we set mid to (L + R) / 2:

L													M															R
12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26		

A simple example was written on the whiteboard during the class.

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Visualization of Binary Search (2)

Since target (33) < array[mid] (61), we set R to mid - 1:

L R M

12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Since found is false and L <= R, we set mid to (L + R) / 2:

M R

L

12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

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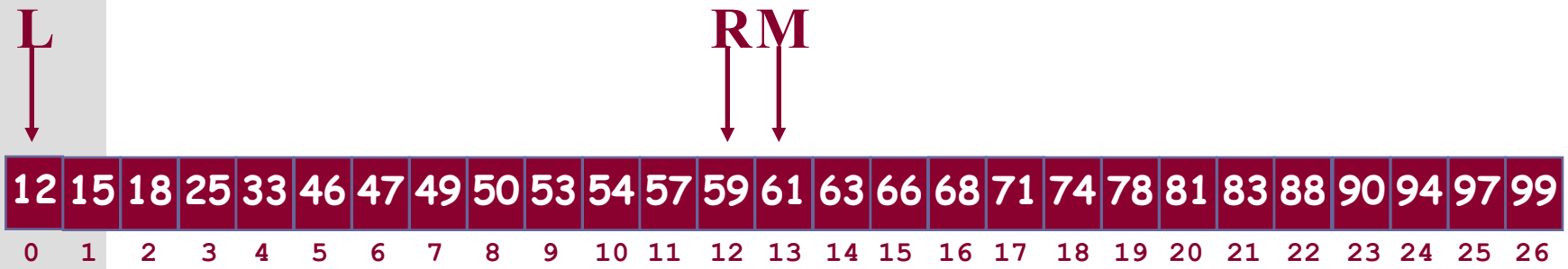
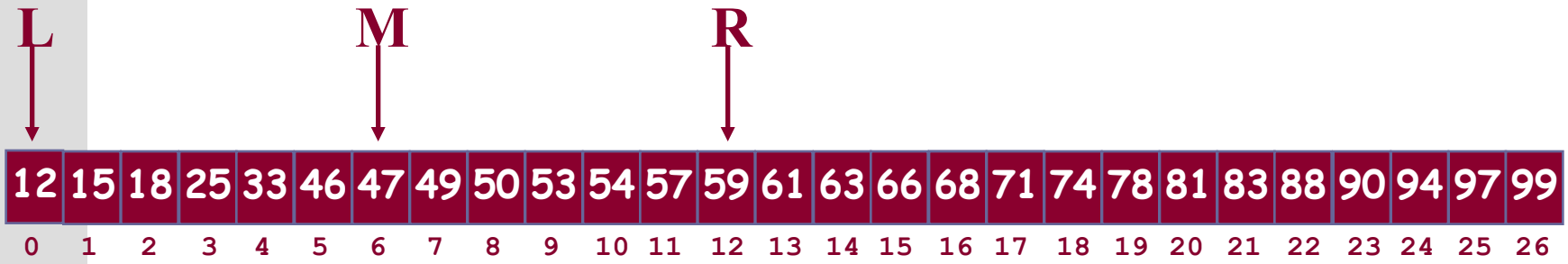
Visualization of Binary Search (3)

Since target (33) < array[mid] (47), we set R to mid - 1:



Since found is false and L <= R, we set mid to (L + R) / 2:



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Visualization of Binary Search (4)

Since target (33) < array[mid] (47), we set R to mid - 1:

L					R	M																				
12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Since found is false and L <= R, we set mid to (L + R) / 2:

L		M			R																					
12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

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Visualization of Binary Search (5)

Since target (33) > array[mid] (18), we set L to mid + 1:

M L R

12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Since found is false and L <= R, we set mid to (L + R) / 2:

L M R

12	15	18	25	33	46	47	49	50	53	54	57	59	61	63	66	68	71	74	78	81	83	88	90	94	97	99
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

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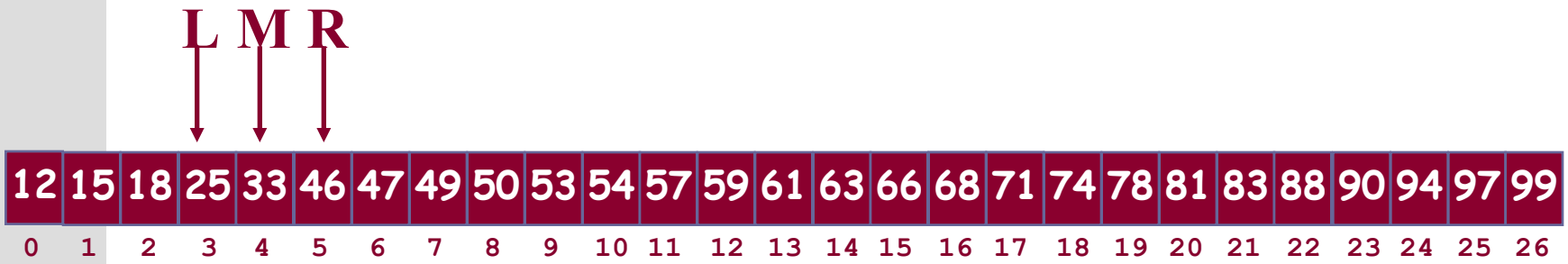
Visualization of Binary Search (6)

Since target (33) == array[mid] (33), we set found to true



Since found is true, we return the index of mid (4)

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Array Searching (5)

- C adaptation of binary search (compiled and tested!)

```
int binary_search(int values[], int target, int num_values)
{
        int found, left, right, mid;
        found = 0; /* false */
        left = 0;
        right = num_values;
        while (!found && left <= right)
        {
          mid = (left + right)/2;
          if (target == values[mid])
            found = 1; /* true */
          else if (target < values[mid])
            right = mid - 1;
          else /* target > values[mid] */
            left = mid + 1;
        }
        if (found)
          return (mid);
        else
          return (NOT_FOUND); /* #defined to -1 */
}
```


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Array Sorting (1)

- Lots of motivating problems
  - Print out a class list in alphabetical order
  - Order finish times in a race to determine who placed
  - Make look-up easier (preparation for binary search)

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Array Sorting (2)

- Selection Sort
  - *Input*: a list of numbers
  - *Output*: a list of the same numbers in ascending order
  - *Method*:
    - Set marker that divides “sorted” and “unsorted” sections of list to the beginning of the list
    - While the unsorted section of the list is not empty
      - Call upon Find_Smallest helper function to find index of smallest value in “unsorted” section of list
      - Swap smallest value in "unsorted section of list" with first value in “unsorted” section of list
      - Move "sorted/unsorted" marker left one position

Pseudo code and graphs were drawn on the white board in the class.

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Array Sorting (3)

- C adaptation of selection sort (compiled and tested!)

```
void selection_sort(int values[], int num_values)
{
  int i, index_of_smallest, temp;
  for (i = 0; i < num_values - 1; ++i)
  {
    /* Find the index of the smallest element in unsorted list... */
    index_of_smallest = find_smallest(values,i,num_values-1);
    /* Swap the smallest value in the subarray i+1 .. num_values - 1
        with the value i, thereby putting into place the ith element. */
    temp = values[i];
    values[i] = values[index_of_smallest];
    values[index_of_smallest] = temp;
  }
}

int find_smallest(int values[], int low, int high)
{
  int smallest_index, i;
  smallest_index = low;
  for (i = low + 1; i <= high; i++)
    if (values[i] < values[smallest_index])
      smallest_index = i;
  return smallest_index;
}
```


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References

- J.R. Hanly & E.B. Koffman, *Problem Solving and Program Design in C (8th Ed.)*, Addison-Wesley, 2016
- P.J. Deitel & H.M. Deitel, *C How to Program (7th Ed.)*, Pearson Education , Inc., 2013.

Collaborators

- Chris Hundhausen
- Andrew O'Fallon