Searching

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Review

- We introduce a lots of variants of binary search tree, which is the fundamental
  - Huffman Tree is created in 1952
    - Data compression
  - Binary Search Tree, 1960
  - AVL Tree, 1962
    - Proposed by Georgy **A**delson-**V**elsky & Evgenii **L**andis

  - 2-3 Tree, 1970
  - Red-Black Tree, 1972
    - std::map in C++
      - ✓ The re-balance process is faster than AVL tree
  - B Tree, 1972
    - A B-tree of order 3 is a 2-3 tree
  - B+ Tree, 1973
    - NTFS uses B+ trees for directory and security-related metadata indexing
    - MySQL indexing
  - Splay Tree, 1985
    - For memory management algorithms

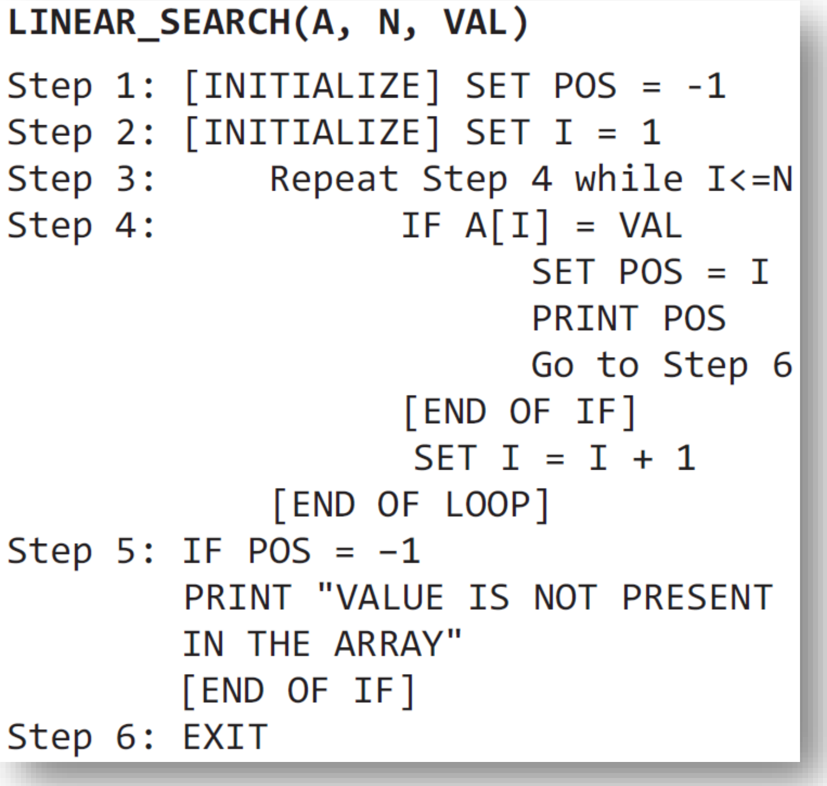
Searching

- Searching means to find whether a particular value is present in an array or not

- There are two popular methods for searching the array elements: **linear search** and **binary search**
  - The algorithm that should be used depends entirely on how the values are organized in the array
    - If the elements of the array are arranged in ascending order, then binary search should be used
    - If the elements are randomly arranged in an array, then linear search should be used

Linear Search

- Linear search, also called as **sequential search**, is a very simple method used for searching an array for a particular value
  - It works by comparing the value to be searched with every element of the array one by one in a sequence until a match is found
  - It is mostly used to **search an unordered** list of elements



```
LINEAR_SEARCH(A, N, VAL)

Step 1: [INITIALIZE] SET POS = -1
Step 2: [INITIALIZE] SET I = 1
Step 3:     Repeat Step 4 while I<=N
Step 4:           IF A[I] = VAL
                        SET POS = I
                        PRINT POS
                        Go to Step 6
                  [END OF IF]
                   SET I = I + 1
            [END OF LOOP]
Step 5: IF POS = -1
        PRINT "VALUE IS NOT PRESENT
        IN THE ARRAY"
        [END OF IF]
Step 6: EXIT
```

Binary Search

- Binary search is a searching algorithm that works efficiently with a **sorted** list
  - Initially, BEG = lower_bound, END = upper_bound, and POS = MID
  - If VAL is not equal to A[MID], then the values of BEG, END, and MID will be changed depending on whether VAL is smaller or greater than A[MID]
    - If VAL < A[MID], then VAL will be present in the left segment of the array

      The value of END will be changed as END = MID – 1
    - If VAL > A[MID], then VAL will be present in the right segment of the array

      The value of BEG will be changed as BEG = MID + 1

Example

- For a data array, please find 7

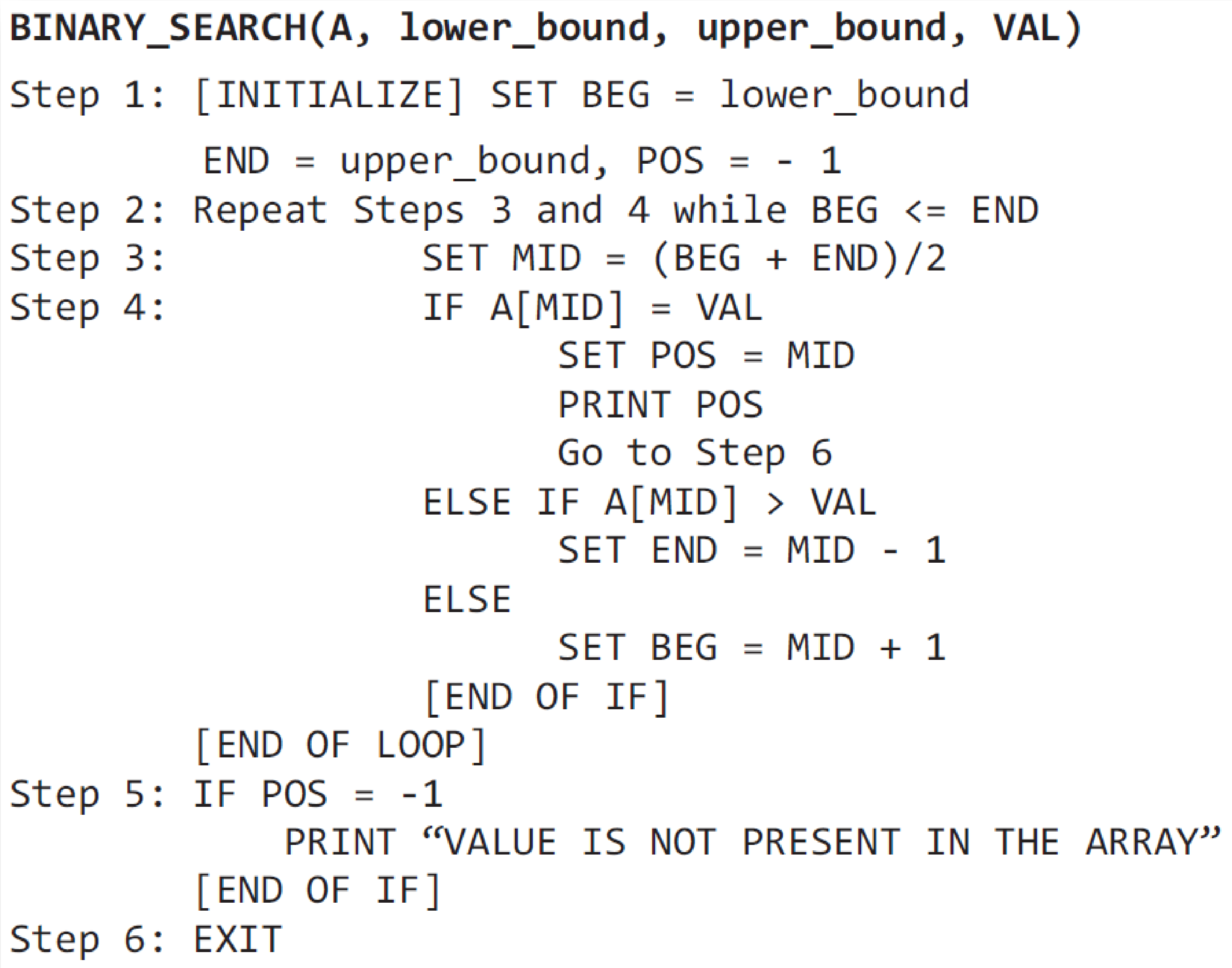
```
int A[] = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
```

  - Step1: BEG = 0, END = 10, MID = (0 + 10)/2 = 5
    - A[MID] = A[5] = 5

  - Step2: BEG = MID + 1 = 6, END = 10, MID = (6 + 10)/2 =16/2 = 8
    - A[MID] = A[8] = 8

  - Step3: BEG = 6, END = MID— 1=7, MID= (6 + 7)/2 = 7
    - A[MID] = A[7] = 7

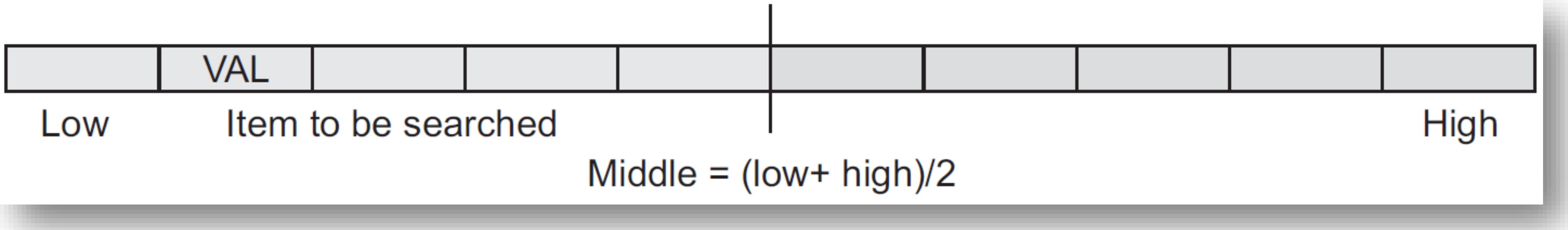
Binary Search – Algorithm



```
BINARY_SEARCH(A, lower_bound, upper_bound, VAL)
Step 1: [INITIALIZE] SET BEG = lower_bound
        END = upper_bound, POS = - 1
Step 2: Repeat Steps 3 and 4 while BEG <= END
Step 3:           SET MID = (BEG + END)/2
Step 4:           IF A[MID] = VAL
                        SET POS = MID
                        PRINT POS
                        Go to Step 6
                  ELSE IF A[MID] > VAL
                        SET END = MID - 1
                  ELSE
                        SET BEG = MID + 1
                  [END OF IF]
        [END OF LOOP]
Step 5: IF POS = -1
            PRINT “VALUE IS NOT PRESENT IN THE ARRAY”
        [END OF IF]
Step 6: EXIT
```

Interpolation Search

- Interpolation search, also known as extrapolation search, is a searching technique that finds a specified value in a **sorted array**
  - Interpolation search is similar to the binary search technique

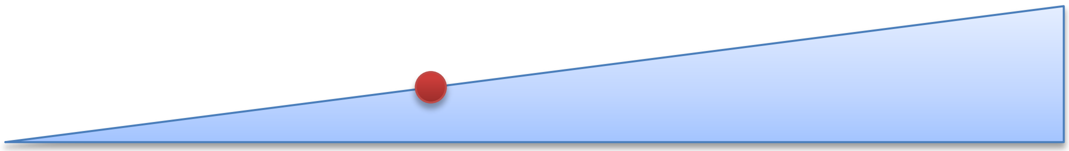


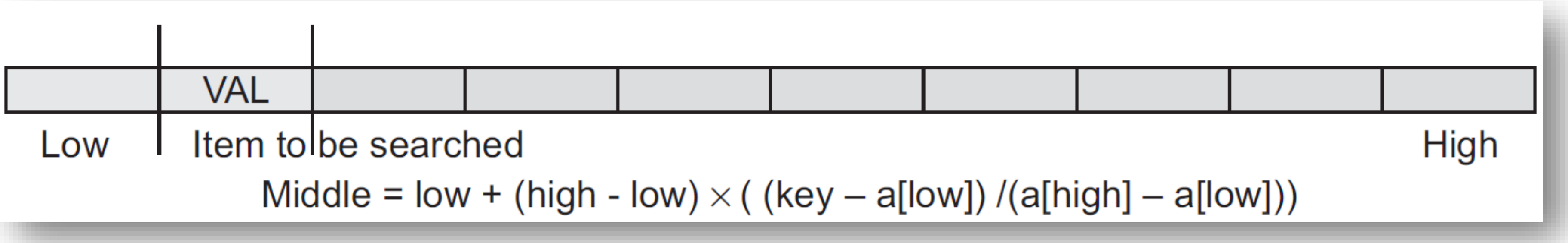
VAL

Low Item to be searched High

Middle = (low+ high)/2

  - The major difference is how to select the middle value





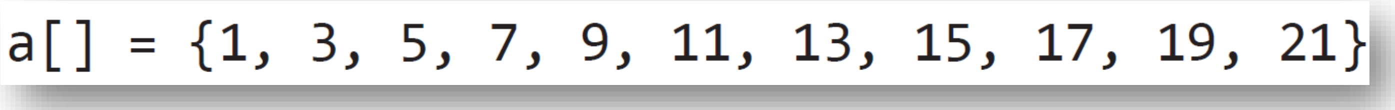
VAL

Low Item to be searched High

Middle = low + (high - low) × ((key – a[low]) /(a[high] – a[low]))

Example

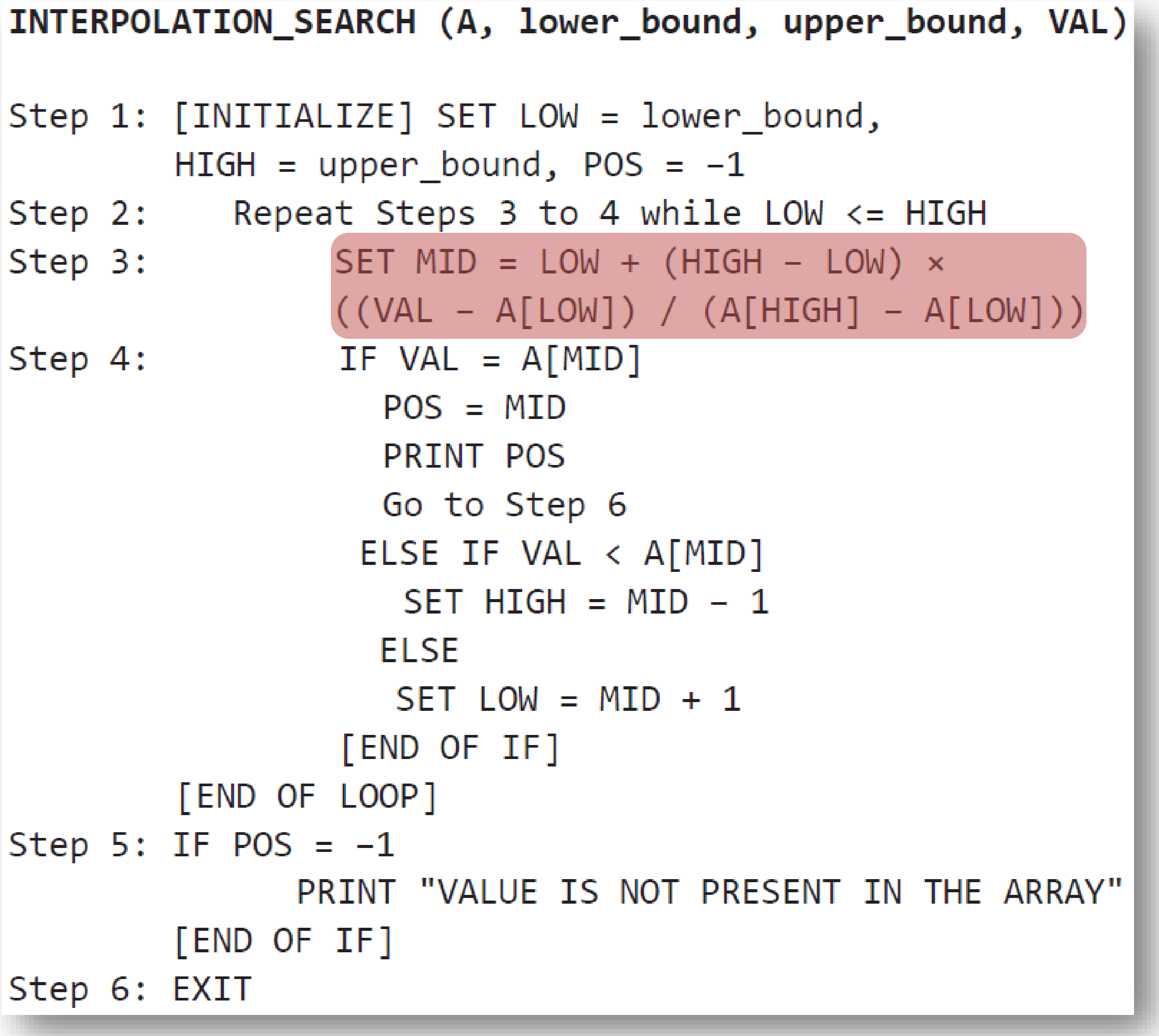
- Given a list of numbers, please search for value 19 using interpolation search technique



```
a[] = {1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21}
```

  - Low = 0, High = 10, VAL = 19
  - a[Low] = 1, a[High] = 21
  - Middle
    = Low + (High – Low)×((VAL – a[Low]) /(a[High] – a[Low]))
    = 0 +(10 – 0) × ((19 – 1) / (21 – 1))
    = 0 + 10 × 0.9 = 9
  - a[Middle] = a[9] = 19

Interpolation Search – Algorithm



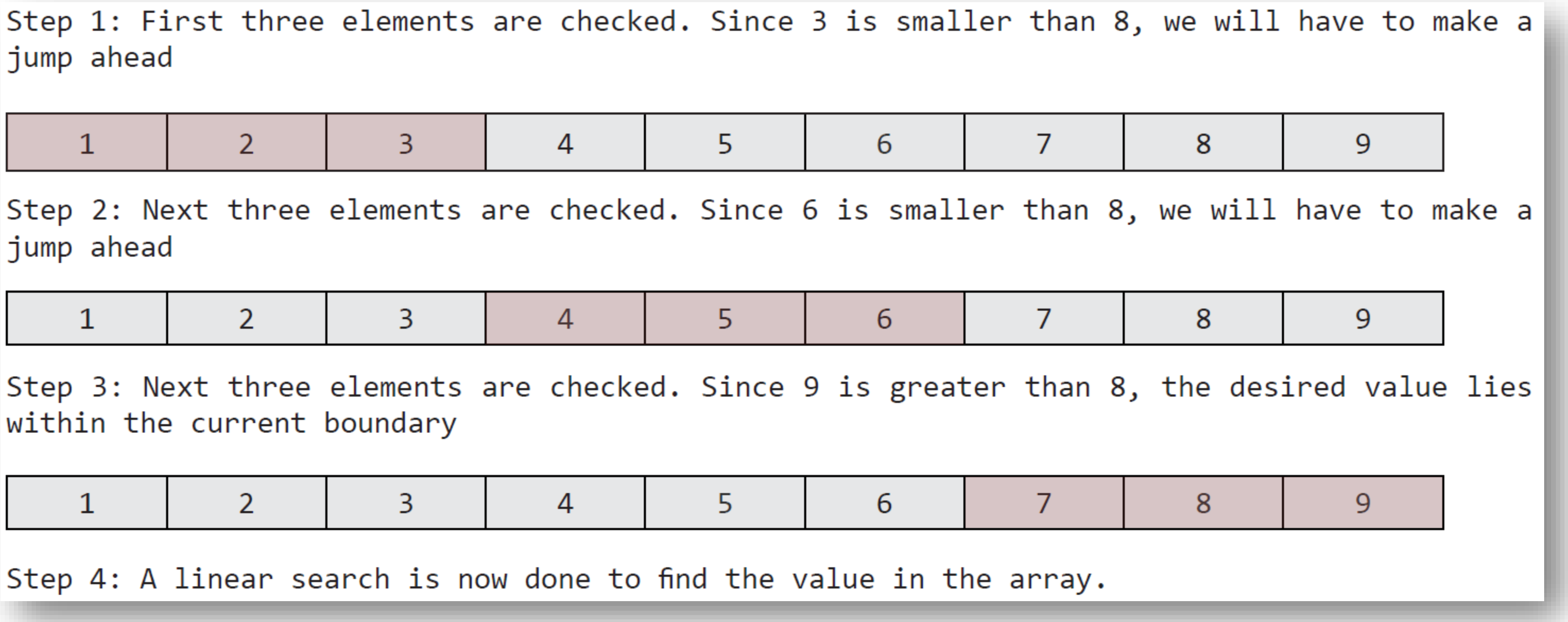
```
INTERPOLATION_SEARCH (A, lower_bound, upper_bound, VAL)

Step 1: [INITIALIZE] SET LOW = lower_bound,
        HIGH = upper_bound, POS = -1
Step 2:    Repeat Steps 3 to 4 while LOW <= HIGH
Step 3:         SET MID = LOW + (HIGH - LOW) ×
                ((VAL - A[LOW]) / (A[HIGH] - A[LOW]))
Step 4:         IF VAL = A[MID]
                  POS = MID
                  PRINT POS
                  Go to Step 6
                 ELSE IF VAL < A[MID]
                   SET HIGH = MID - 1
                  ELSE
                   SET LOW = MID + 1
                [END OF IF]
        [END OF LOOP]
Step 5: IF POS = -1
              PRINT "VALUE IS NOT PRESENT IN THE ARRAY"
        [END OF IF]
Step 6: EXIT
```

Jump Search

- When we have an already **sorted list**, then the other efficient algorithm to search for a value is jump search or block search
  - Segmental linear search
  - Given an array, please find value 8

```
a[] = {1,2,3,4,5,6,7,8,9}
```



Step 1: First three elements are checked. Since 3 is smaller than 8, we will have to make a jump ahead

1	2	3	4	5	6	7	8	9

Step 2: Next three elements are checked. Since 6 is smaller than 8, we will have to make a jump ahead

1	2	3	4	5	6	7	8	9

Step 3: Next three elements are checked. Since 9 is greater than 8, the desired value lies within the current boundary

1	2	3	4	5	6	7	8	9

Step 4: A linear search is now done to find the value in the array.

Schedule

- Midterm exam will be held at 11/7 (Mon.) 10:20~12:10

Questions?

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