http://www.cs.cornell.edu/courses/cs1110/2018sp

Lecture 27: Sorting & Searching

CS 1110

Introduction to Computing Using Python

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Announcements

- Academic Integrity:
  - Remember to cite your sources
- Assignment 5
  - Due 11:59pm on ***<u>**Wednesday**</u>*** May 9th
  - Please see webpage for updates/clarifications
- Last Lab due this week in your Lab Section.
- Final Exam
  - May 17th, 9am-11:30am
  - **Location**: Barton Hall Central and East
  - Conflict assignment on CMS

Final Exam Review Session

- Hollister B14 from 12-3:30

Saturday May 12:

- - Lists/Sequences (12-1)
- - Loop invariants/sequence algorithms (1-2)
- - Problem solving session (2-3:30)

Sunday May 13:

- - Call frames (12-1)
- - Classes (1-2)
- - Problem solving session (2-3:30)

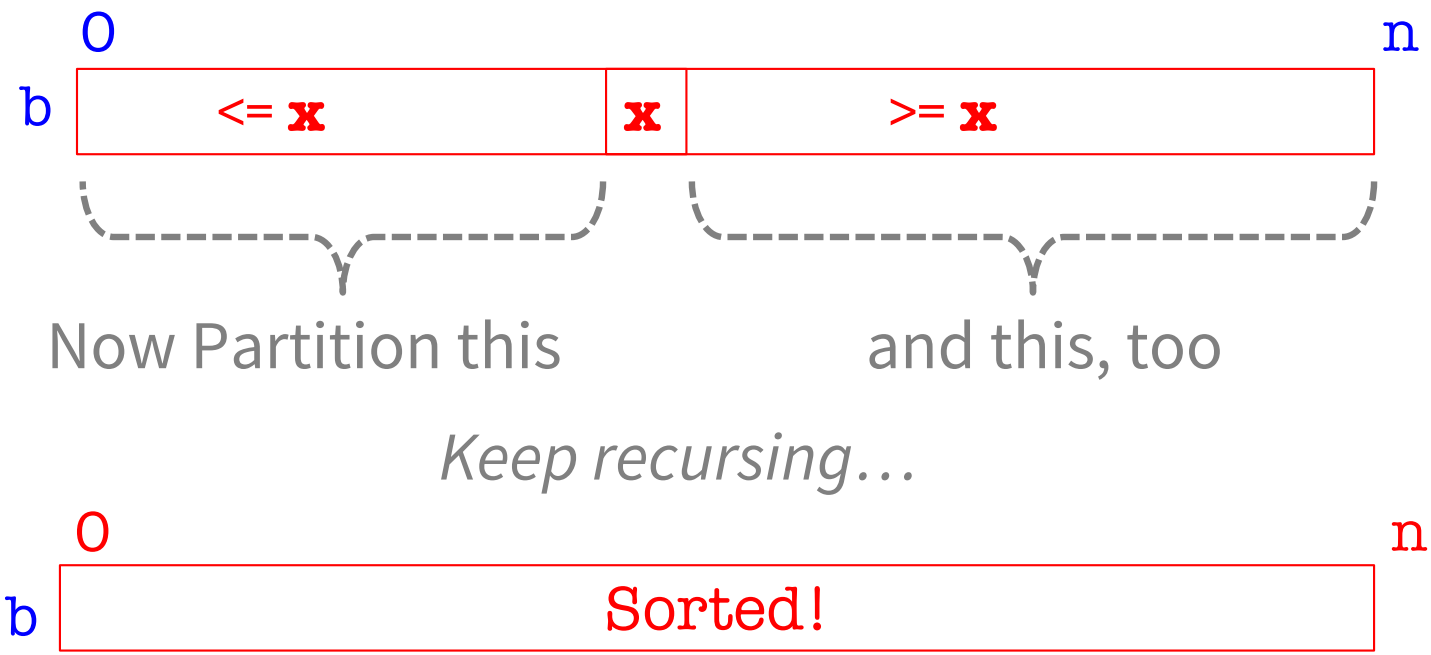
Last Week's Plan of Attack

- Insertion Sort
- Partition
- Quick Sort

Where we left off

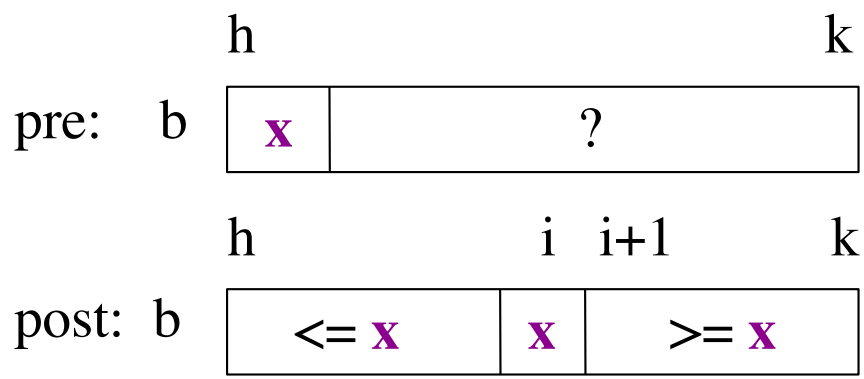
Sorting with Partitions

- **Idea:** Pick a *pivot* element **x**
- Partition sequence into <= x and >= x



QuickSort

```
def quick_sort(b, h, k):
    """Sort the array fragment b[h..k]"""
    if  k<=h:
        return
    i = partition(b, h, k)
    # INV: b[h..i-1] <= b[i] <= b[i+1..k]
    # Sort b[h..i-1]  and  b[i+1..k]
    quick_sort (b, h, i-1)
    quick_sort (b, i+1, k)
```



https://www.youtube.com/watch?v=m1PS8IR6TdO

Quicksort in the real world

```
DEFINE JOBINTERVIEWQUICKSORT(LIST):
    OK SO YOU CHOOSE A PIVOT
    THEN DIVIDE THE LIST IN HALF
    FOR EACH HALF:
        CHECK TO SEE IF IT'S SORTED
            NO, WAIT, IT DOESN'T MATTER
        COMPARE EACH ELEMENT TO THE PIVOT
            THE BIGGER ONES GO IN A NEW LIST
            THE EQUAL ONES GO INTO, UH
            THE SECOND LIST FROM BEFORE
        HANG ON, LET ME NAME THE LISTS
            THIS IS LIST A
            THE NEW ONE IS LIST B
        PUT THE BIG ONES INTO LIST B
        NOW TAKE THE SECOND LIST
            CALL IT LIST, UH, A2
        WHICH ONE WAS THE PIVOT IN?
        SCRATCH ALL THAT
        IT JUST RECURSIVELY CALLS ITSELF
        UNTIL BOTH LISTS ARE EMPTY
            RIGHT?
        NOT EMPTY, BUT YOU KNOW WHAT I MEAN
    AM I ALLOWED TO USE THE STANDARD LIBRARIES?
```

https://xkcd.com/1185/

Today's Plan of Attack

- Quick Sort
- Linear Search
- Binary Search

Linear Search

- **Vague**: Find first occurrence of v in b[h..k-1].
- **Better**: Store an integer in **i** to make this post-condition true:

  post: 1. v is not in b[h.. **i**-1]

  2. **i** = k OR v = b[**i**]

Linear Search

- **Vague**: Find first occurrence of v in b[h..k-1].
- **Better**: Store an integer in **i** to make this post-condition true:

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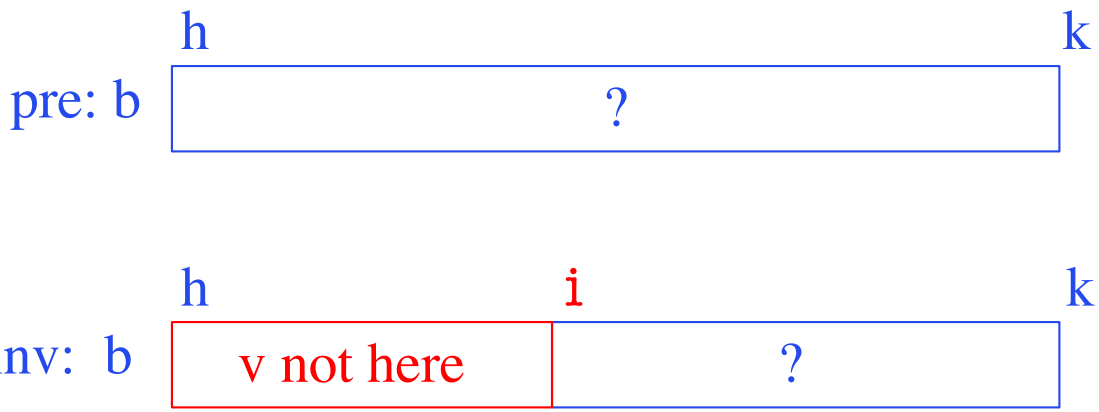
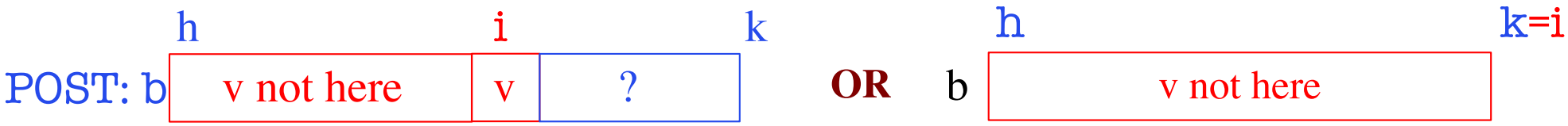
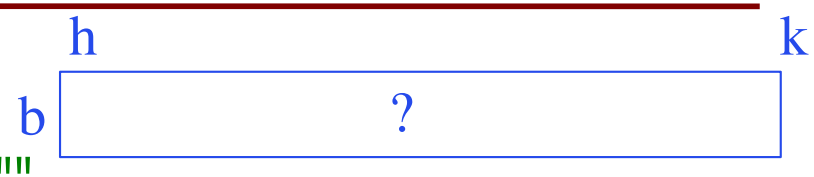




Linear Search




```
def linear_search(b,v,h,k):
    """Returns: first occurrence of v in b[h..k-1]"""
    # Store in i index of the first v in b[h..k-1]
    i = h

    # invariant: v is not in b[0..i-1]
    while i < k and b[i] != v:
        i = i + 1

    # post: v is not in b[h..i-1]
    #       i >= k or b[i] == v
    return i if i < k else -1
```

Analyzing the Loop

1. Does the initialization make **inv** true?

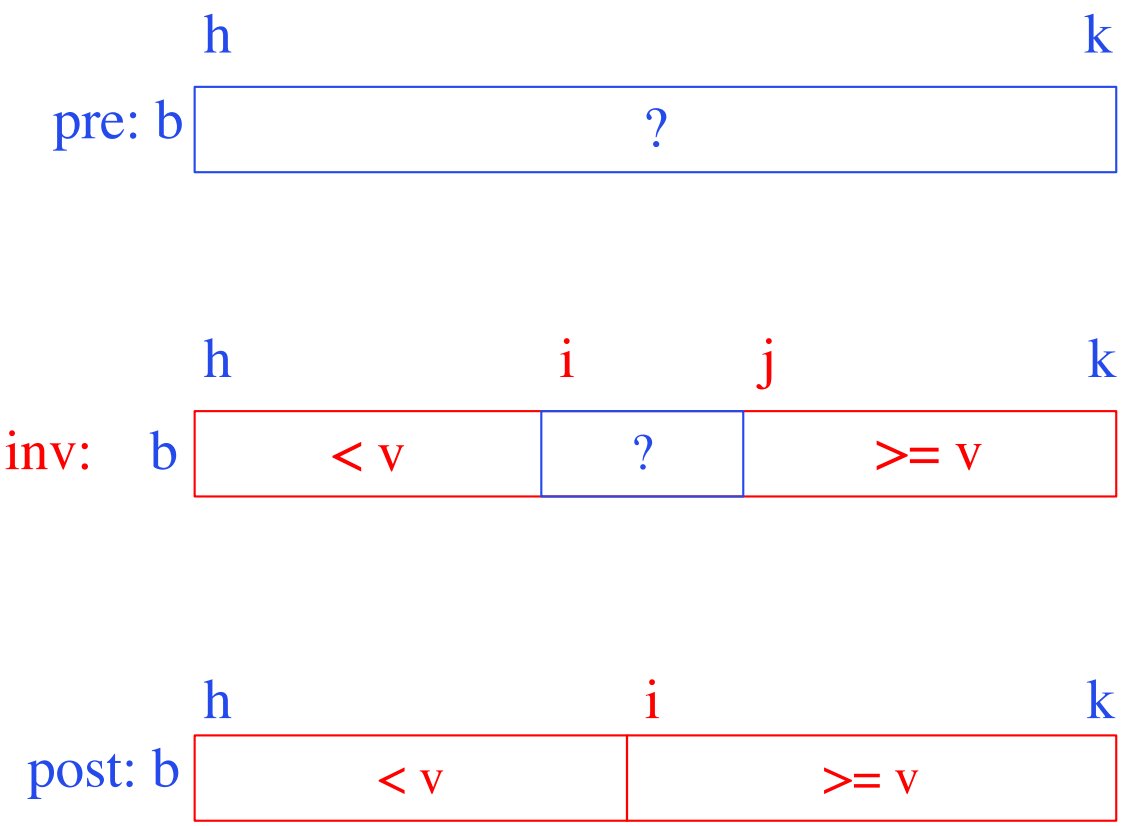
2. Is **post** true when **inv** is true and **condition** is false?

3. Does the repetend make progress?

4. Does the repetend keep the invariant **inv** true?

Binary Search: What's the Invariant?

- Look for v in **sorted** sequence segment b[h..k].
  - Precondition: b[h..k-1] is sorted (in ascending order).
  - Postcondition: b[h..i-1] < v and v <= b[i..k]



Called binary search because each iteration of the loop cuts the array segment still to be processed in half

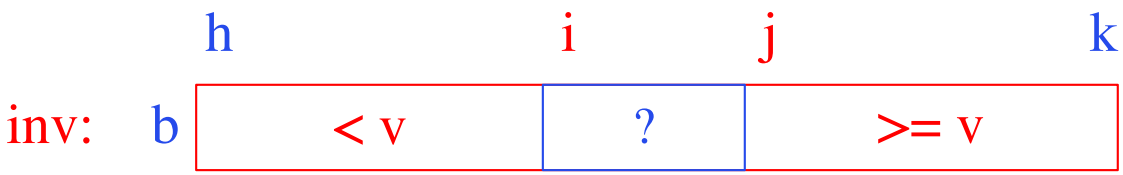
Binary Search

	h									k
	0	1	2	3	4	5	6	7	8	9
Example b	3	3	3	3	3	4	4	6	7	7

- if v is 3, set i to 0
- if v is 4, set i to 5
- if v is 5, set i to 7
- if v is 8, set i to 10

Binary Search


```
i = h; j = k+1;
```

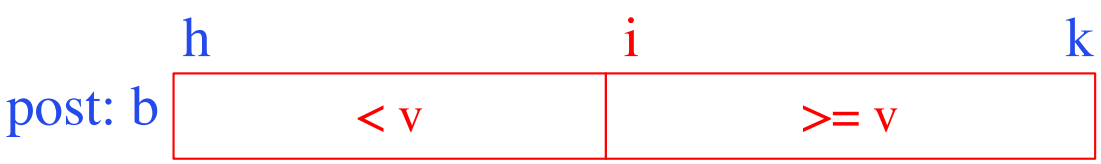



```
while i != j:
```

Looking at b[i] gives linear search from left.

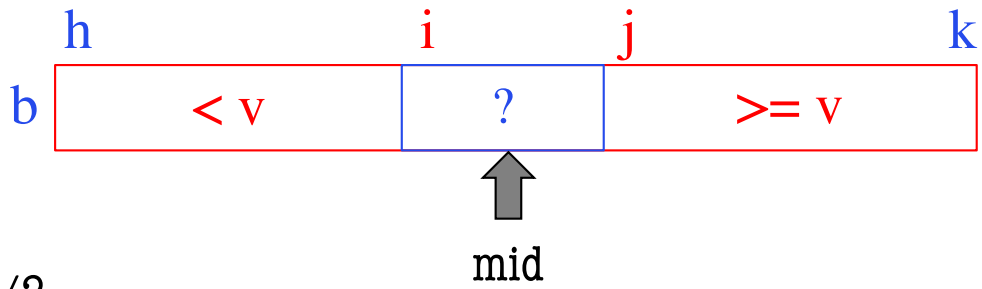
Looking at b[j-1] gives linear search from right.

Looking at middle: b[(i+j)/2] gives binary search.

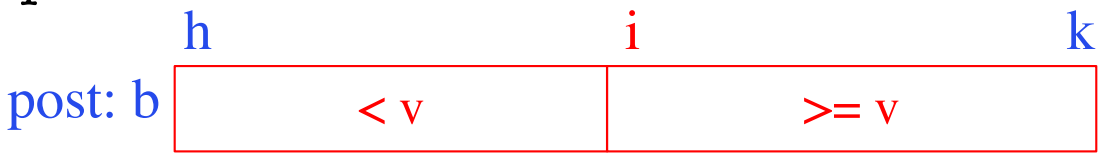


Binary Search


```
def bsearch(b, v):
    i = 0
    j = len(b)
```




```
    while i < j:
        mid = (i+j)/2
        if b[mid] < v:
            i = mid+1
        else: #b[mid] >= v
            j = mid
    if i< len(b) and b[i] == v:
        return i
    else:
        return -1
```



Analyzing Binary Search

```
def bsearch(b, v):
    i = 0
    j = len(b)
    # invariant; b[0..i-1] < v, b[i..j-1] unknown, b[j..] >= v
    while i < j:
        mid = (i+j)/2
        if b[mid] < v:
            i = mid+1
        else: #b[mid] >= v
            j = mid

    if i< len(b) and b[i] == v:
        return i
    else:
        return -1
```

Analyzing the Loop

1. Does the initialization make **inv** true?

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Binary Search Recursive

```
def rbsearch(b, v):
    """ len(b) > 0 """
    return rbsearch_helper(b, v, 0, len(b))
```

```
def rbsearch_helper(b, v, i, j):
    if i >= j:
        if i < len(b) and b[i] == v:
            return i
        else:
            return -1

    mid = (i + j) / 2

    if b[mid] < v:
        return rbsearch_helper(b, v, mid + 1, j)
    else: # b[mid] >= v
        return rbsearch_helper(b, v, i, mid)
```