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한동대학교 전산전자공학부

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Data Structures in Python
Chapter 5 - 2

- Merge sort
- **Quick sort Algorithm**
- Quick sort Analysis
- Empirical Analysis

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Agenda & Readings

- Agenda
  - Quick sort algorithm
    - $n \log(n)$ algorithm,
    - Divide and conquer algorithm
- Reference:
  - Problem Solving with Algorithms and Data Structures
    - Chapter 5 Search, Sorting and Hashing: Quick sort
    - Wikipedia Quick sort
    - [알고리즘] 퀵정렬

Quick sort

- Quick sort invented by British computer scientist C.A.R. Hoare in 1960
- Quick sort is another divide and conquer algorithm.
- Time complexity is $O(n \log n)$ average, $O(n^2)$ worst case, faster than merge sort in general.

Quick sort - Algorithm

- Choose a pivot element from the array. Although we can choose any element in the array as a pivot, it's easy to implement if we choose the rightmost element of the subarray.

index	0	1	2	3	4	5	6	7	8	9
value	32	23	81	43	92	39	57	16	75	65

pivot

- Partition or reorder the array so that all values smaller than the pivot are moved before it and all values larger (or equal) than the pivot are moved after it.

32	23	43	39	57	16	92	81	75	65

pivot

  - When this is done, the pivot is in its final position.

32	23	43	39	57	16	65	81	75	92

sorted

- Conquer by repeating steps above for the left side and right side of the pivot recursively, except the pivot itself since it is sorted and positioned at the right place,

Quick sort - Partition

- Choose a pivot element and partition the array in place such that all elements to the left of the pivot element are smaller, while all elements to the right are greater than the pivot.

index	0	1	2	3	4	5	6	7	8	9
value	32	23	81	43	92	39	57	16	75	65
j=lo i=lo-1	j=0 i=0	j=1 i=1	j=2 i=1	j=3 i=2	j=4 i=2	j=5 i=3	j=6 i=4	j=7 i=5	j=8 i=5	pivot

while **j** traverses from **low** to **hi-1**
i increments only when **a[j] < pivot**

```
def partition(a, lo, hi):
    pivot = a[hi]
    i = lo - 1;
    j = lo
    while j <= hi - 1:                    scan
        if a[j] < pivot:
            i += 1
            if i != j:                    swap
                a[j], a[i] = a[i], a[j]
        j += 1
    a[hi], a[i+1] = a[i+1], a[hi]         sorted
    return i + 1
```

Quick sort - Partition

- Choose a pivot element and partition the array in place such that all elements to the left of the pivot element are smaller, while all elements to the right are greater than the pivot.

index	0	1	2	3	4	5	6	7	8	9
value	32	23	81	43	92	39	57	16	75	65
j=lo i=lo-1	j=0 i=0	j=1 i=1	j=2 i=1	j=3 i=2 swap	j=4 i=2	j=5 i=3 swap	j=6 i=4 swap	j=7 i=5 swap	j=8 i=5	pivot

Now, find elements to swap.

```
while j traverses from low to hi-1
i increments only when a[j] < pivot
```

```
def partition(a, lo, hi):
    pivot = a[hi]
    i = lo - 1;
    j = lo
    while j <= hi - 1:                    scan
        if a[j] < pivot:
            i += 1
            if i != j:                    swap
                a[j], a[i] = a[i], a[j]
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```

Quick sort - Partition

- Choose a pivot element and partition the array in place such that all elements to the left of the pivot element are smaller, while all elements to the right are greater than the pivot.

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swap(2,3)	32	23	43	81	92	39	57	16	75	65
swap(3,5)	32	23	43	39	92	81	57	16	75	65
swap(4,6)	32	23	43	39	57	81	92	16	75	65
swap(5,7)	32	23	43	39	57	16	92	81	75	65

not sorted

while **j** traverses from **low** to **hi-1**
i increments only when **a[j] < pivot**

```
def partition(a, lo, hi):
    pivot = a[hi]
    i = lo - 1;
    j = lo
    while j <= hi - 1:                    scan
        if a[j] < pivot:
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            if i != j:                    swap
                a[j], a[i] = a[i], a[j]
        j += 1
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    return i + 1
```
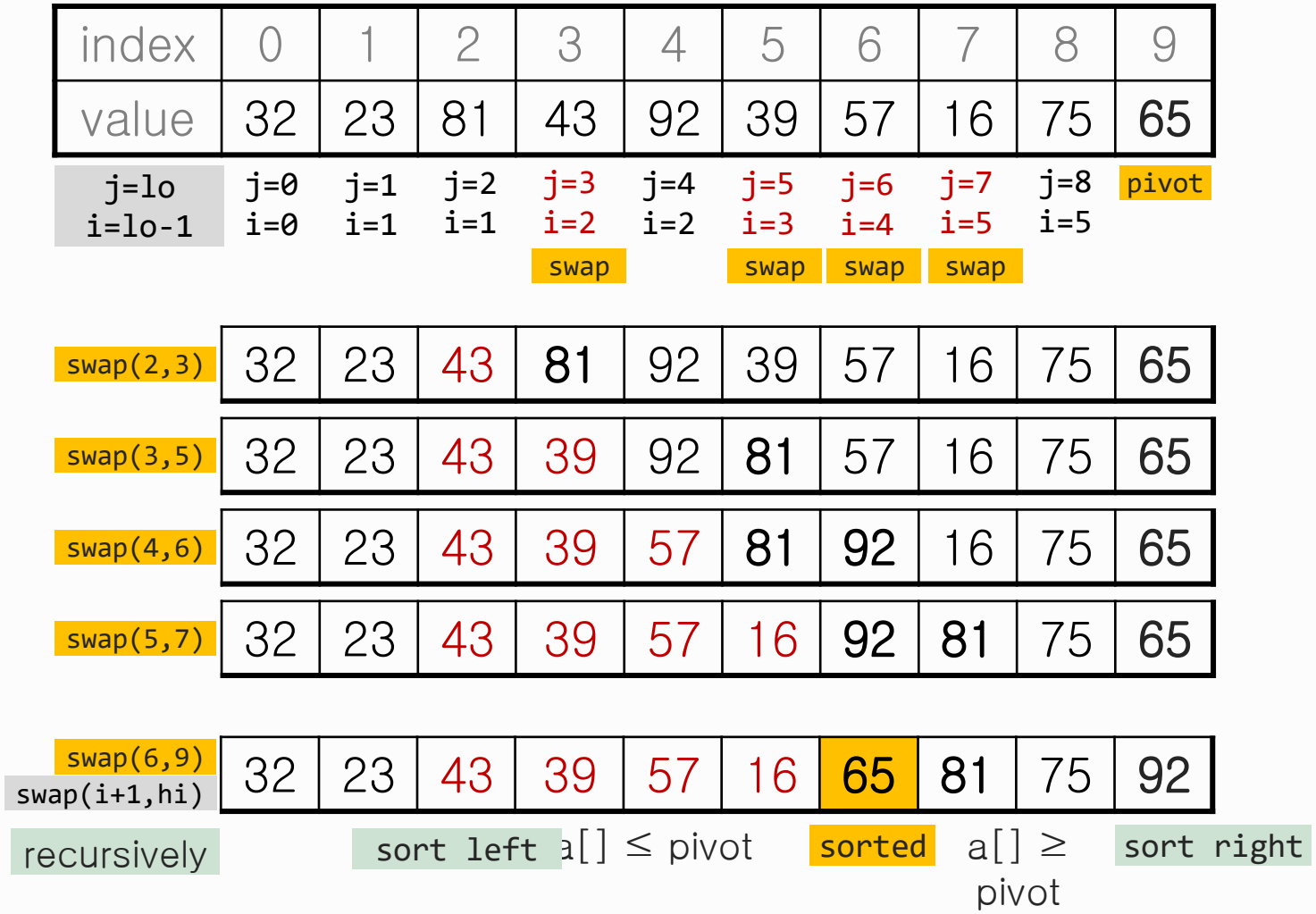

Quick sort - Partition

- Choose a pivot element and partition the array in place such that all elements to the left of the pivot element are smaller, while all elements to the right are greater than the pivot.




```
while j traverses from low to hi-1
i increments only when a[j] < pivot
```

```
def partition(a, lo, hi):
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                a[j], a[i] = a[i], a[j]
        j += 1
    a[hi], a[i+1] = a[i+1], a[hi]         sorted
    return i + 1
```
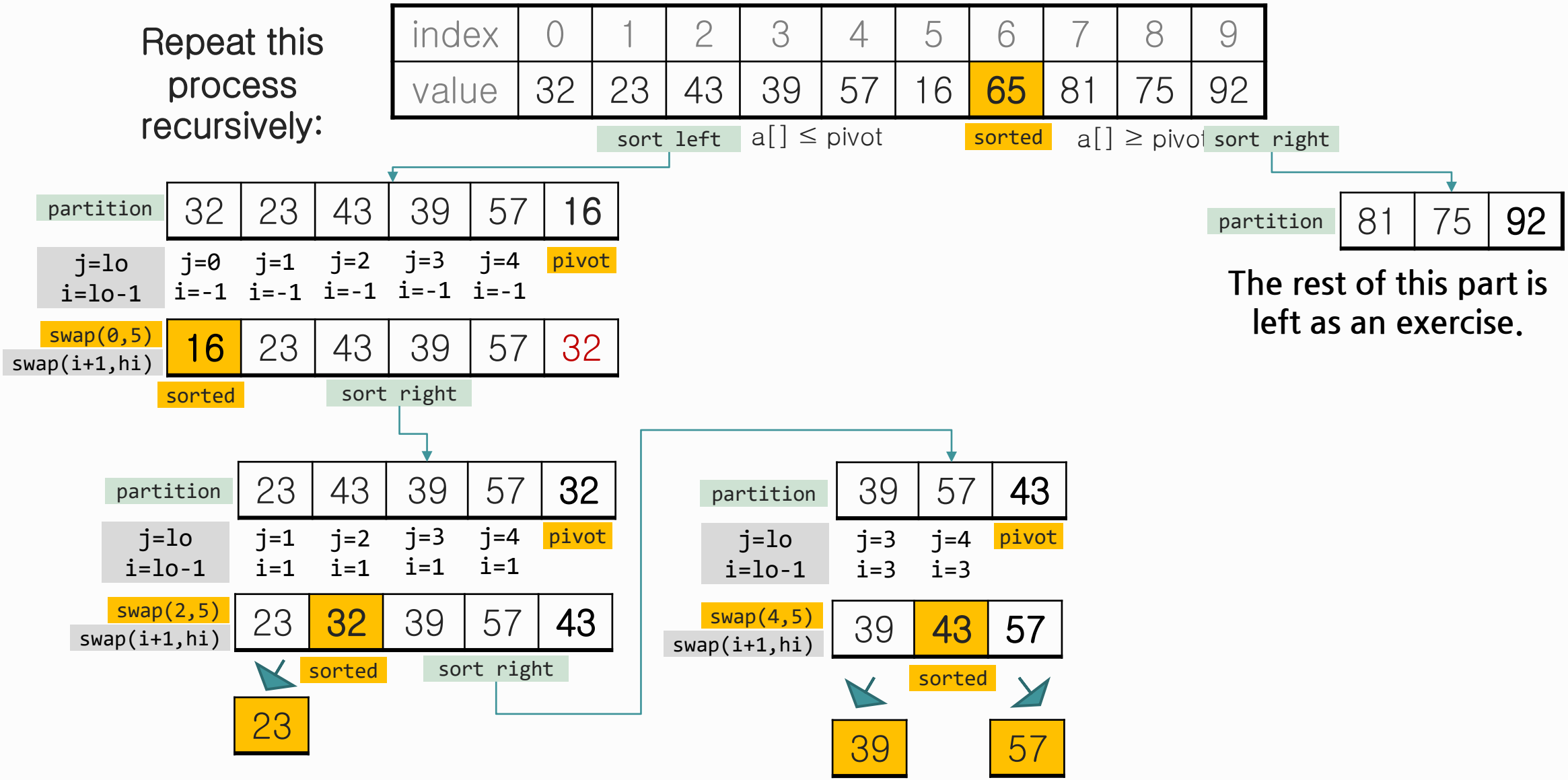
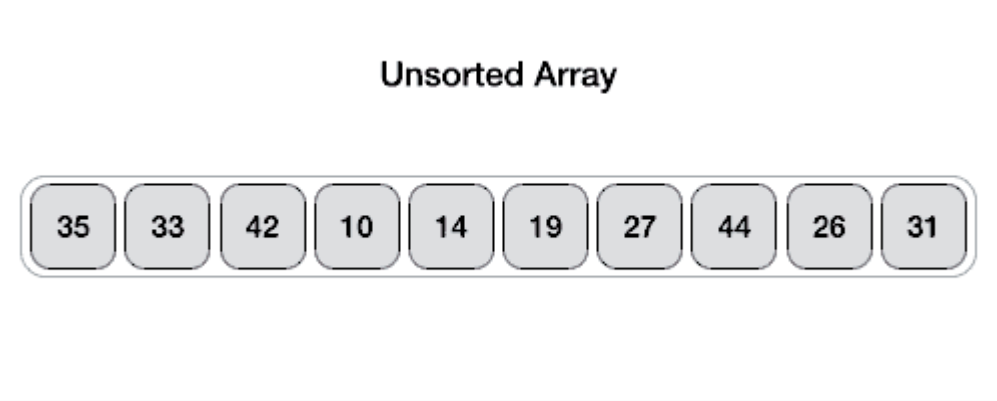

Quick sort - Partition

Repeat this process recursively:



Summary

- Quick sort is one of the most efficient sorting algorithms.
- It is based on the splitting of an array (**partition**) into smaller ones and rearrange based on the comparison with '**pivot**' element selected.
- Like merge sort, quick sort also falls into the category of **divide and conquer** approach of problem-solving methodology.



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