

Quick Sort

- Find an item in a sorted item [List or Array or String]
- Highly efficient in terms of time complexity against Linear Search
- Run time Complexity : $O(\log n)$
- Based on divide and conquer technique

Example

Sort the given array

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Partitioning

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Step 6) Continue until left \geq right

Partitioning

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Partitioning

Left

Right

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left -> 0 , right -> length - 1

Partitioning

Left

Right

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|----|----|---|----|---|---|
| 11 | 4 | 17 | 18 | 2 | 22 | 1 | 8 |
|----|---|----|----|---|----|---|---|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Step 6) Continue until left \geq right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|----|---|----|---|----|
| 11 | 4 | 8 | 18 | 2 | 22 | 1 | 17 |
|----|---|---|----|---|----|---|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 22 | 18 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 22 | 18 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Step 6) Continue until left $>$ right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 22 | 18 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 22 | 18 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Step 5) Swap the value of left with right

Step 6) Continue until left $>$ right

Partitioning

Left

Right

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Partitioning

Right

Left

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Partitioning

Right

Left

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

Partitioning

Right

Left

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 1) Get the pivot (left most)

Step 2) Set 2 Pointers : left \rightarrow 0 , right \rightarrow length - 1

Step 3) Increment left until you find that number \geq pivot

Step 4) Decrement right until you find that number \leq pivot

right < left \rightarrow hence the loop has to break

Partitioning

Right

Left

| | | | | | | | |
|----|---|---|---|---|----|----|----|
| 11 | 4 | 8 | 1 | 2 | 18 | 22 | 17 |
|----|---|---|---|---|----|----|----|

Pivot = 11

Step 7) Swap the value of pivot with right

Partitioning

Right

Left

| | | | | | | | |
|---|---|---|---|----|----|----|----|
| 2 | 4 | 8 | 1 | 11 | 18 | 22 | 17 |
|---|---|---|---|----|----|----|----|

Pivot = 11

Step 7) Swap the value of pivot with right

Now, we found partitioning position :: All left side has smaller and all right has bigger

Recursion on left

Left

Right

| | | | | |
|---|---|---|---|----|
| 2 | 4 | 8 | 1 | 11 |
|---|---|---|---|----|

Pivot = 2

Recursion on left

Left

Right

| | | | | |
|---|---|---|---|----|
| 2 | 4 | 8 | 1 | 11 |
|---|---|---|---|----|

Pivot = 2

Recursion on left

Left

Right

| | | | | |
|---|---|---|---|----|
| 2 | 4 | 8 | 1 | 11 |
|---|---|---|---|----|

Pivot = 2

Recursion on left

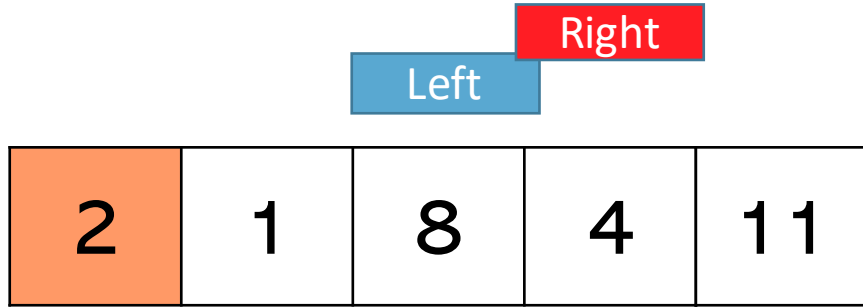
Left

Right

| | | | | |
|---|---|---|---|----|
| 2 | 1 | 8 | 4 | 11 |
|---|---|---|---|----|

Pivot = 2

Recursion on left



Pivot = 2

Recursion on left

Right
Left

| | | | | |
|---|---|---|---|----|
| 2 | 1 | 8 | 4 | 11 |
|---|---|---|---|----|

Pivot = 2

Recursion on left

Right
Left

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 8 | 4 | 11 |
|---|---|---|---|----|

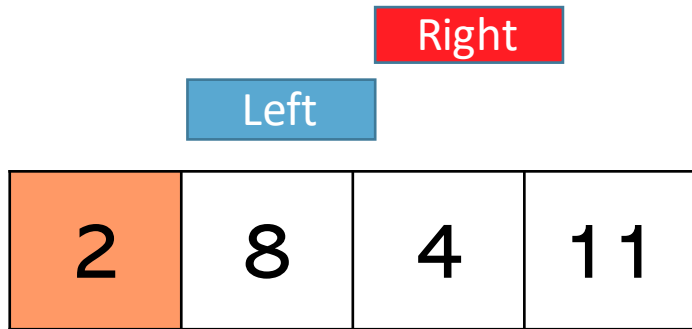
Pivot = 1

Recursion on right

| Left | Right | | |
|------|-------|---|----|
| 2 | 8 | 4 | 11 |

Pivot = 2

Recursion on right



Pivot = 2

Recursion on right

Right

Left

| | | | |
|---|---|---|----|
| 2 | 8 | 4 | 11 |
|---|---|---|----|

Pivot = 2

Recursion on right

Right

Left

| | | | |
|---|---|---|----|
| 2 | 8 | 4 | 11 |
|---|---|---|----|

Pivot = 2

Recursion on right

| Left | Right |
|------|-------|
| 8 | 4 11 |

Pivot = 8

| | |
|---|---|
| 1 | 2 |
|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left
Right

| | | |
|---|---|----|
| 8 | 4 | 11 |
|---|---|----|

Pivot = 8

| | |
|---|---|
| 1 | 2 |
|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

| | | |
|---|---|----|
| 8 | 4 | 11 |
|---|---|----|

Pivot = 8

| | |
|---|---|
| 1 | 2 |
|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

| | | |
|---|---|----|
| 4 | 8 | 11 |
|---|---|----|

Pivot = 8

| | |
|---|---|
| 1 | 2 |
|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

8

11

Pivot = 8

1

2

4

18

22

17

Recursion on right

Left

Right

| | |
|---|----|
| 8 | 11 |
|---|----|

Pivot = 8

| | | |
|---|---|---|
| 1 | 2 | 4 |
|---|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

| | |
|---|----|
| 8 | 11 |
|---|----|

Pivot = 8

| | | |
|---|---|---|
| 1 | 2 | 4 |
|---|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

| | |
|---|----|
| 8 | 11 |
|---|----|

Pivot = 8

| | | |
|---|---|---|
| 1 | 2 | 4 |
|---|---|---|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

Pivot = 8

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Recursion on right

Left

Right

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right

Left

Right

| | | |
|----|----|----|
| 18 | 22 | 17 |
|----|----|----|

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right

| Left | | Right |
|------|----|-------|
| 18 | 22 | 17 |

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

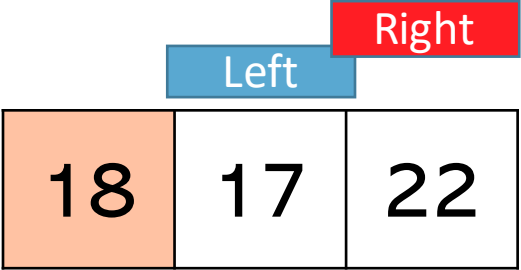
Recursion on right

| Left | | Right |
|------|----|-------|
| 18 | 22 | 17 |

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right



Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right

| <div>Right</div> <div>Left</div> | | |
|----------------------------------|----|----|
| 18 | 17 | 22 |

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right

| | | |
|----|------|-------|
| | | |
| | | Right |
| | Left | |
| 18 | 17 | 22 |

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right

| | | |
|----|----|-------|
| | | |
| | | Right |
| | | Left |
| 17 | 18 | 22 |

Pivot = 18

| | | | | |
|---|---|---|---|----|
| 1 | 2 | 4 | 8 | 11 |
|---|---|---|---|----|

Recursion on right

Right

| | |
|----|----|
| 18 | 22 |
|----|----|

Pivot = 18

Left

| | | | | | |
|---|---|---|---|----|----|
| 1 | 2 | 4 | 8 | 11 | 17 |
|---|---|---|---|----|----|

Recursion on right

Right

| | |
|----|----|
| 18 | 22 |
|----|----|

Left

Pivot = 18

| | | | | | |
|---|---|---|---|----|----|
| 1 | 2 | 4 | 8 | 11 | 17 |
|---|---|---|---|----|----|

Recursion on right

Right

| | |
|----|----|
| 18 | 22 |
|----|----|

Left

Pivot = 18

| | | | | | |
|---|---|---|---|----|----|
| 1 | 2 | 4 | 8 | 11 | 17 |
|---|---|---|---|----|----|

Recursion on right

Right

| | |
|----|----|
| 18 | 22 |
|----|----|

Left

Pivot = 18

| | | | | | |
|---|---|---|---|----|----|
| 1 | 2 | 4 | 8 | 11 | 17 |
|---|---|---|---|----|----|

Recursion on right

| | | | | | | | |
|---|---|---|---|----|----|----|----|
| 1 | 2 | 4 | 8 | 11 | 17 | 18 | 22 |
|---|---|---|---|----|----|----|----|