Selection Sort

09114319: Data Structures and Algorithms

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Outline

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  - How memory works
  - Arrays and linked lists
  - Comparisons of data structures
- Introduction to Selection Sort
  - Problem setup: Sorting a list
  - Algorithm description
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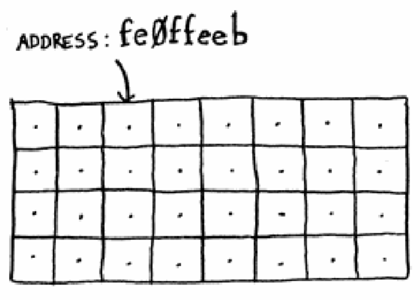
- Code Implementations
- Applications of Selection Sort
- Recap

How Memory Works

✎ Computer memory is like a giant set of drawers.

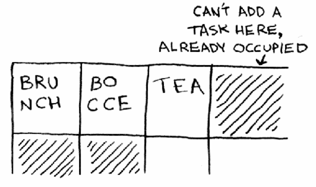
How Memory Works

- Each drawer has a unique address, used to store items.

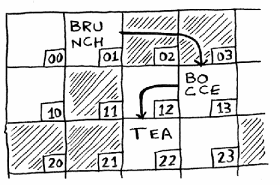


To store multiple items:

✎ Use an array: all items are stored contiguously.



✎ Use a linked list: items can be scattered but linked by addresses.



Arrays and Linked Lists

Arrays

- ✎ Items stored next to each other in memory.
- ✎ Fast random access: $O(1)$ for reads.
- ✎ Slow inserts: $O(n)$ if shifting or resizing is needed.
- ✎ Arrays are great for fast reads and situations requiring random access.

Linked Lists

- ✎ Items scattered in memory.
- ✎ Fast inserts and deletes: $O(1)$ if the pointer is known.
- ✎ Slow reads: Sequential access required ($O(n)$).
- ✎ Linked lists are ideal for frequent inserts and deletes.

When to Use Arrays vs. Linked Lists?

Data Structure	**Reading**	**Inserting**	**Deleting**
Arrays	$O(1)$	$O(n)$	$O(n)$
Linked Lists	$O(n)$	$O(1)$	$O(1)$

- Use arrays when:
  - Fast random access is needed.
  - Memory is contiguous and resizing is minimal.
- Use linked lists when:
  - Frequent inserts and deletes are required.
  - Memory does not need to be contiguous.
- Both structures are foundational for implementing algorithms like sorting.

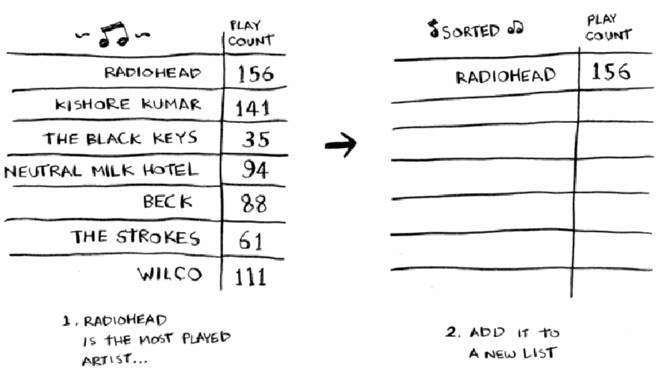
Problem Setup: Sorting a List

- ✎ Suppose you have a list of music artists with play counts.
- ✎ Goal: Sort the list from most played to least played.

♫	PLAY COUNT
RADIOHEAD	156
KISHORE KUMAR	141
THE BLACK KEYS	35
NEUTRAL MILK HOTEL	94
BECK	88
THE STROKES	61
WILCO	111

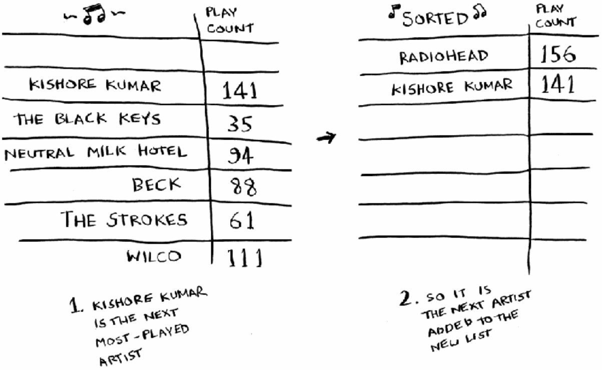
How can you achieve this?

- ✎ Start by finding the most played artist.
- ✎ Add that artist to a new list.



How can you achieve this?

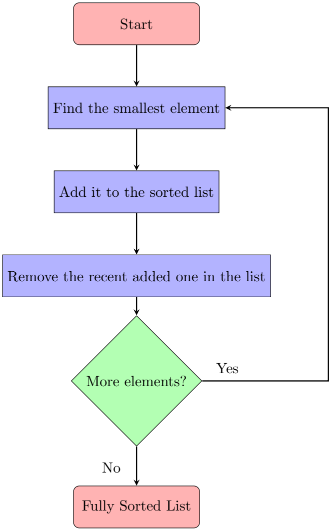
- ✎ Repeat for the remaining artists.



- ✎ This approach is the basis of the **Selection Sort** algorithm.

What is Selection Sort?

- A simple algorithm for sorting a list.
- Process:
  1. Find the smallest (or largest) element in the list.
  2. Add it to a new sorted list.
  3. Remove the recent added one from the list.
  4. Repeat for all remaining elements.
- Result: A fully sorted list.



Selection Sort in Action

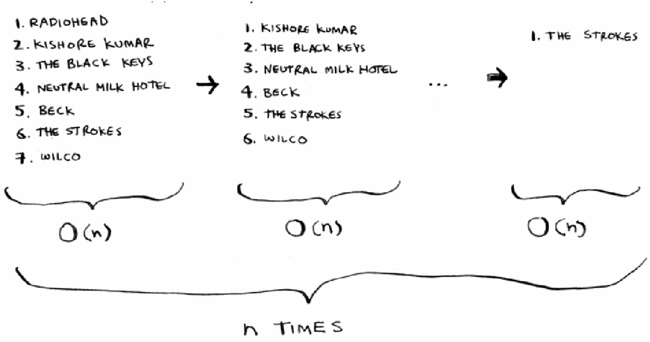
- ✎ Example: Sort the list $[5, 3, 6, 2, 10]$.
- ✎ Steps:
  1. Find the smallest number (2).
  2. Add 2 to the new list.
  3. Remove 2 from the original list.
  4. Repeat until the original list is empty.
- ✎ Output: $[2, 3, 5, 6, 10]$

Key Characteristics of Selection Sort

- ✎ **Deterministic Algorithm**: Same input produces the same output.
- ✎ **Comparison-Based Sorting**: Involves pairwise comparisons of elements.
- ✎ **Not Adaptive**: Does not optimize for partially sorted lists.
- ✎ **In-Place Sorting**: Requires no extra space beyond the original list (when implemented in-place).

Use Cases for Selection Sort

- Simple scenarios with small datasets.
- Educational purposes: Demonstrates sorting mechanics.
- Limited memory environments: Can be implemented in-place.
- Not ideal for large datasets due to its $O(n^2)$ time complexity.



Performance of Selection Sort

- Selection Sort has a time complexity of $O(n^2)$.
- Why $O(n^2)$?
  - To find the smallest element, you must check all n elements.
  - Repeat the process for the remaining $n-1$, $n-2$, ..., 1 elements.
  - Total comparisons:
    $$n + (n-1) + (n-2) + ... + 1 = \frac{n(n+1)}{2}.$$
  - This simplifies to $O(n^2)$ as constants are ignored in Big O notation.

Space Complexity of Selection Sort

- Space complexity is $O(1)$.
- Selection Sort operates in-place:
  - Does not require additional memory for a new list.
  - Sorting happens within the original list.
- Efficient in terms of memory usage.

Selection Sort vs. Other Algorithms

Advantages

- Simple to implement.
- Works well on small datasets.
- Requires minimal memory.

Disadvantages

- Poor performance on large datasets due to $O(n^2)$.
- Not adaptive: No advantage for partially sorted data.
- Slow compared to more advanced algorithms like Quicksort or Merge Sort.

Analyzing $O(n^2)$ Complexity

- Example: Sorting a list of size $n = 10$:
  - Comparisons: $10 + 9 + 8 + ... + 1 = 55$.
- Doubling the input size to $n = 20$:
  - Comparisons: $20 + 19 + 18 + ... + 1 = 210$.
- Observations:
  - Number of comparisons grows quadratically.
  - Doubling the input size increases work by 4 times ($O(n^2)$).

When is Selection Sort Practical?

- ✎ Small datasets where $O(n^2)$ is acceptable.
- ✎ When memory usage is a critical concern ($O(1)$ space complexity).
- ✎ Educational purposes: Explaining sorting mechanics and $O(n^2)$ complexity.
- ✎ When simplicity of implementation is preferred over performance.

Step 1: Finding the Smallest Element

- ✎ Write a function to find the smallest element in an array.
- ✎ This helper function will be used repeatedly in Selection Sort.

```
def findSmallest(arr):
    smallest = arr[0]  # Stores the smallest value
    smallest_index = 0  # Stores the index of the
    ↪  smallest value
    for i in range(1, len(arr)):
        if arr[i] < smallest:
            smallest = arr[i]
            smallest_index = i
    return smallest_index
```

Step 2: Sorting the Array

- Use the ‘findSmallest‘ function to implement Selection Sort.
- Iteratively find the smallest element and build a new sorted array.

```python
def selectionSort(arr):
    newArr = []
    for i in range(len(arr)):
        smallest = findSmallest(arr)  # Find the
        ↪  smallest element
        newArr.append(arr.pop(smallest))  # Add it
        ↪  to the new array
    return newArr
```

Example: Running Selection Sort

Input Example:

- ✎ Sort the array $[5, 3, 6, 2, 10]$ using Selection Sort.

```
print(selectionSort([5, 3, 6, 2, 10]))
# Output: [2, 3, 5, 6, 10]
```

Explanation:

- ✎ Finds the smallest element (2) and adds it to the new array.
- ✎ Repeats the process for all elements until the array is sorted.

Sorting Without a New Array

- ✎ Modify Selection Sort to sort the original array in place.
- ✎ Reduces space complexity to $O(1)$.

```python
def selectionSortInPlace(arr):
    for i in range(len(arr)):
        smallest_index = i
        for j in range(i + 1, len(arr)):
            if arr[j] < arr[smallest_index]:
                smallest_index = j
        arr[i], arr[smallest_index] =
        ↪  arr[smallest_index], arr[i]
    return arr
```

Discussion Points

- What are the advantages of the in-place implementation?
- How does the `findSmallest` function work in tandem with the main sorting logic?
- Compare the in-place version with the version that creates a new array:
  - Space complexity
  - Code clarity

Advantages of the In-Place Implementation

- **Memory Efficiency:**
  - Reduces space complexity from $O(n)$ to $O(1)$.
  - No need to create and manage an additional array.
- **Practical Use:**
  - Preferred for large datasets where memory usage is a concern.
  - Common in real-world applications where overhead must be minimized.

How the `findSmallest` Function Works

- Identifies the smallest element in the unsorted portion of the array.
- **Non-In-Place Version:**
  - The smallest element is removed from the original array.
  - It is appended to a new array, progressively building the sorted list.
- **In-Place Version:**
  - Logic is integrated into the nested loop to find the smallest element.
  - The smallest element is swapped with the current index, avoiding the creation of a new array.

In-Place vs. Non-In-Place Implementations

Feature	Non-In-Place	In-Place
Space Complexity	$O(n)$: Requires a new array	$O(1)$: No additional memory
Time Complexity	$O(n^2)$	$O(n^2)$
Code Simplicity	Easier to understand	Slightly more complex
Use Case	Learning or small datasets	Large datasets, memory-constrained environments

Summary of the Comparison

- **Non-In-Place Version:**
  - Simple and intuitive for educational purposes.
  - Suitable for small-scale applications.
- **In-Place Version:**
  - More efficient for large datasets.
  - Requires a deeper understanding of memory management.

Applications of Selection Sort

- **Small Datasets**:
  - Selection Sort is simple and efficient for small input sizes.
- **Memory-Constrained Environments**:
  - Minimal space requirements make it practical for limited-memory systems.
- **Educational Purposes**:
  - Ideal for teaching sorting mechanics and complexity analysis.
- **Sorting Data by Priority**:
  - Useful when processing data with explicit priority order (e.g., finding top scores).

Limitations of Selection Sort

- ✎ Poor performance on large datasets ($O(n^2)$).
- ✎ Not adaptive: Does not leverage partial sorting.
- ✎ Slower compared to advanced algorithms like Quicksort ($O(n \log n)$).

Looking Ahead

- **Next Steps in Sorting**:
  - Learn faster sorting algorithms, such as Quicksort and Merge Sort.
  - Understand when to use different sorting approaches.
- **Practical Use Cases**:
  - Sorting names in a phone book.
  - Organizing data by timestamps (e.g., emails or events).
  - Ranking items (e.g., playlists, scores, priorities).
- **Broader Applications**:
  - Sorting is a fundamental operation in numerous algorithms and systems.
  - Real-world optimizations often combine sorting with other techniques (e.g., search).

Recap: Key Concepts

- **Memory and Data Structures**:
  - Arrays: Contiguous memory, fast random access ($O(1)$).
  - Linked Lists: Scattered memory, efficient inserts/deletes ($O(1)$).
- **Selection Sort Algorithm**:
  - Iteratively finds the smallest (or largest) element.
  - Builds a sorted list step by step.
  - Time complexity: $O(n^2)$.
  - Space complexity: $O(1)$ (in-place implementation).