```
!pip install memory_profiler
```

```
Collecting memory_profiler
  Downloading memory_profiler-0.61.0-py3-none-any.whl.metadata (20 kB)
Requirement already satisfied: psutil in /usr/local/lib/python3.12/dist-packages (from
Downloading memory_profiler-0.61.0-py3-none-any.whl (31 kB)
Installing collected packages: memory_profiler
Successfully installed memory_profiler-0.61.0
```

```
# ============================================
# ALGORITHM EFFICIENCY MINI PROJECT
# ============================================

import time
import random
import matplotlib.pyplot as plt
plt.figure(figsize=(10,6))
import pandas as pd
from memory_profiler import memory_usage

# ----------------------------
# TASK 2: ALGORITHM IMPLEMENTATIONS
# ----------------------------

def fib_recursive(n):
    if n <= 1:
        return n
    return fib_recursive(n-1) + fib_recursive(n-2)

def fib_dp(n):
    if n <= 1:
        return n
    a, b = 0, 1
    for _ in range(2, n+1):
        a, b = b, a+b
    return b

def merge_sort(arr):
    if len(arr) <= 1:
        return arr
    mid = len(arr)//2
    left = merge_sort(arr[:mid])
    right = merge_sort(arr[mid:])
    return merge(left, right)

def merge(left, right):
    res = []
    i = j = 0
    while i < len(left) and j < len(right):
        if left[i] < right[j]:
            res.append(left[i])
            i += 1
        else:
            res.append(right[j])
```

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            res.append(right[j])
            j += 1
    res.extend(left[i:])
    res.extend(right[j:])
    return res

def quick_sort(arr):
    if len(arr) <= 1:
        return arr
    pivot = arr[len(arr)//2]
    left = [x for x in arr if x < pivot]
    mid = [x for x in arr if x == pivot]
    right = [x for x in arr if x > pivot]
    return quick_sort(left) + mid + quick_sort(right)

def insertion_sort(arr):
    for i in range(1, len(arr)):
        key = arr[i]
        j = i-1
        while j >= 0 and arr[j] > key:
            arr[j+1] = arr[j]
            j -= 1
        arr[j+1] = key
    return arr

def bubble_sort(arr):
    n = len(arr)
    for i in range(n):
        for j in range(0, n-i-1):
            if arr[j] > arr[j+1]:
                arr[j], arr[j+1] = arr[j+1], arr[j]
    return arr

def selection_sort(arr):
    n = len(arr)
    for i in range(n):
        min_idx = i
        for j in range(i+1, n):
            if arr[j] < arr[min_idx]:
                min_idx = j
        arr[i], arr[min_idx] = arr[min_idx], arr[i]
    return arr

def binary_search(arr, target):
    low, high = 0, len(arr)-1
    while low <= high:
        mid = (low+high)//2
        if arr[mid] == target:
            return mid
        elif arr[mid] < target:
            low = mid+1
        else:
            high = mid-1
    return -1

# ----------------------------
# TASK 3: PROFILING FUNCTIONS
```

```
# ----------------------------

def measure_time(func, *args, **kwargs):
    start = time.time()
    func(*args, **kwargs)
    end = time.time()
    return end - start

def measure_memory(func, *args, **kwargs):
    mem_usage = memory_usage((func, args, kwargs), max_iterations=1, interval=0.01)
    return max(mem_usage) - min(mem_usage)

# ----------------------------
# SORTING ALGORITHMS: TIME & MEMORY
# ----------------------------

sizes = [100, 500, 1000, 2000]
algorithms = {
    "Merge Sort": merge_sort,
    "Quick Sort": quick_sort,
    "Insertion Sort": insertion_sort,
    "Bubble Sort": bubble_sort,
    "Selection Sort": selection_sort
}

time_results = {name: [] for name in algorithms}
memory_results = {name: [] for name in algorithms}

for n in sizes:
    arr = [random.randint(0,10000) for _ in range(n)]
    for name, func in algorithms.items():
        t = measure_time(func, arr[:])
        m = measure_memory(func, arr[:])
        time_results[name].append(t)
        memory_results[name].append(m)

# --- Plot Sorting Time ---
for name, times in time_results.items():
    plt.plot(sizes, times, marker="o", label=name)
plt.xlabel("Input Size (n)")
plt.ylabel("Time (seconds)")
plt.title("Sorting Algorithms Time Comparison")
plt.legend()
plt.show()

# --- Plot Sorting Memory ---
for name, mems in memory_results.items():
    plt.plot(sizes, mems, marker="o", label=name)
plt.xlabel("Input Size (n)")
plt.ylabel("Memory (MB)")
plt.title("Sorting Algorithms Memory Comparison")
plt.legend()
plt.show()

# ----------------------------
# FIBONACCI: RECURSIVE vs DP
# ----------------------------
```

```
ns = [5, 10, 20, 30]
times_rec, times_dp = [], []
mem_rec, mem_dp = [], []

for n in ns:
    t = measure_time(fib_recursive, n)
    m = measure_memory(fib_recursive, n)
    times_rec.append(t)
    mem_rec.append(m)

    t = measure_time(fib_dp, n)
    m = measure_memory(fib_dp, n)
    times_dp.append(t)
    mem_dp.append(m)

plt.plot(ns, times_rec, marker="o", label="Recursive Fibonacci (Time)")
plt.plot(ns, times_dp, marker="o", label="DP Fibonacci (Time)")
plt.xlabel("n")
plt.ylabel("Time (seconds)")
plt.title("Fibonacci Time Comparison")
plt.legend()
plt.show()

plt.plot(ns, mem_rec, marker="o", label="Recursive Fibonacci (Mem)")
plt.plot(ns, mem_dp, marker="o", label="DP Fibonacci (Mem)")
plt.xlabel("n")
plt.ylabel("Memory (MB)")
plt.title("Fibonacci Memory Comparison")
plt.legend()
plt.show()

# ----------------------------
# BINARY SEARCH
# ----------------------------
sizes = [10**3, 10**4, 10**5, 10**6]
times_bs, mem_bs = [], []

for n in sizes:
    arr = list(range(n))
    target = n-1
    times_bs.append(measure_time(binary_search, arr, target))
    mem_bs.append(measure_memory(binary_search, arr, target))

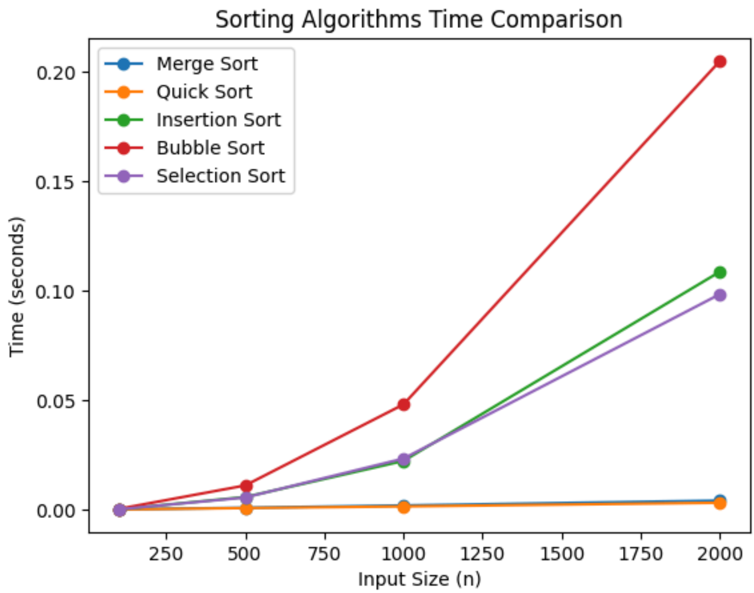
plt.plot(sizes, times_bs, marker="o", label="Binary Search Time")
plt.xlabel("Input Size (n)")
plt.ylabel("Time (seconds)")
plt.title("Binary Search Performance")
plt.legend()
plt.show()

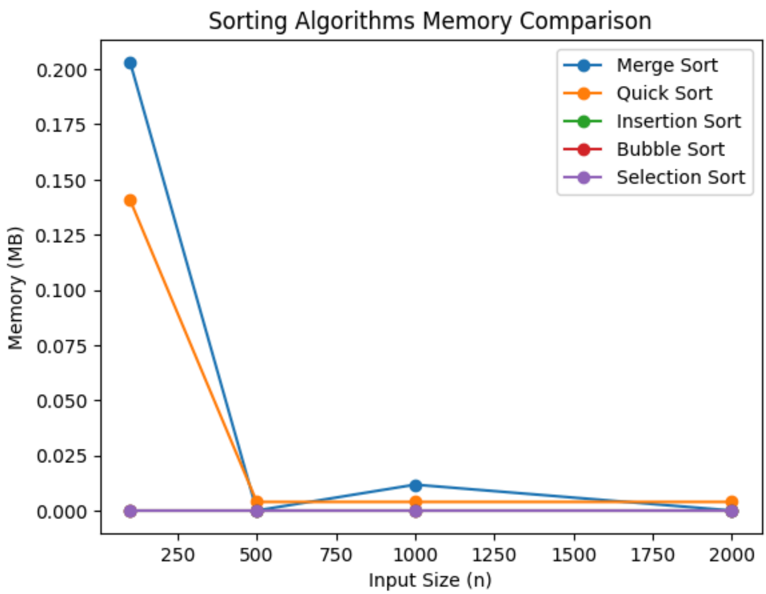
plt.plot(sizes, mem_bs, marker="o", label="Binary Search Memory")
plt.xlabel("Input Size (n)")
plt.ylabel("Memory (MB)")
plt.title("Binary Search Memory Usage")
plt.legend()
plt.show()
```

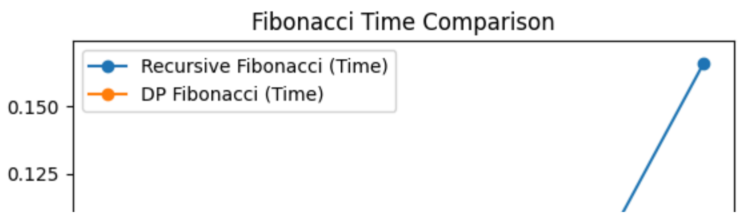
```
# ----------------------------
# COMPLEXITY TABLE (THEORETICAL)
# ----------------------------
print("{:<20} {:<12} {:<12} {:<12} {:<12}".format("Algorithm", "Best", "Average", "Worst",
print("-"*70)
print("Fibonacci Recursive  {:<12} {:<12} {:<12} {:<12}".format("-", "-", "O(2^n)", "O(n)")
print("Fibonacci DP         {:<12} {:<12} {:<12} {:<12}".format("O(n)", "O(n)", "O(n)", "O(
print("Merge Sort           {:<12} {:<12} {:<12} {:<12}".format("O(n log n)", "O(n log n)",
print("Quick Sort           {:<12} {:<12} {:<12} {:<12}".format("O(n log n)", "O(n log n)",
print("Insertion Sort       {:<12} {:<12} {:<12} {:<12}".format("O(n)", "O(n^2)", "O(n^2)",
print("Bubble Sort          {:<12} {:<12} {:<12} {:<12}".format("O(n)", "O(n^2)", "O(n^2)",
print("Selection Sort       {:<12} {:<12} {:<12} {:<12}".format("O(n^2)", "O(n^2)", "O(n^2)
print("Binary Search        {:<12} {:<12} {:<12} {:<12}".format("O(1)", "O(log n)", "O(log

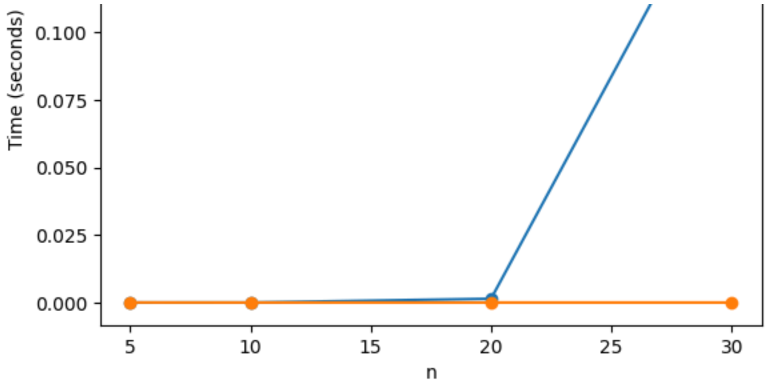
# ----------------------------
# TASK 4: SUMMARY TABLE (EXPERIMENTAL)
# ----------------------------
summary = pd.DataFrame({
    "Input Size": sizes,
    **{name+" Time": time_results[name] for name in time_results},
    **{name+" Mem": memory_results[name] for name in memory_results}
})
print("\nEXPERIMENTAL SUMMARY (Sorting Algorithms):")
print(summary)

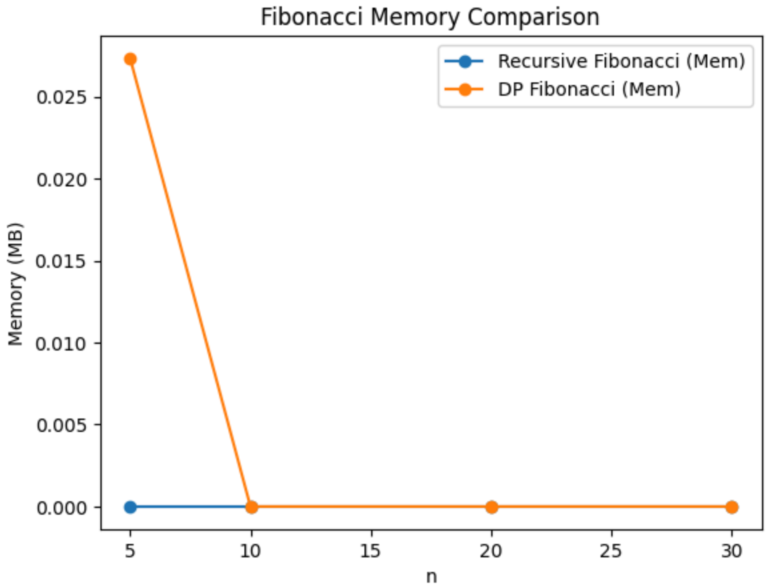
# ----------------------------
# REFLECTIONS
# ----------------------------
print("\n✅ SUMMARY & INSIGHTS")
print("- Fibonacci Recursive is extremely slow for large n (stack depth risk).")
print("- Fibonacci DP is fast and memory efficient.")
print("- Merge Sort and Quick Sort are efficient O(n log n) sorts, though Merge uses more m
print("- Insertion, Bubble, Selection are O(n^2), impractical beyond small n.")
print("- Binary Search is very efficient O(log n), negligible memory, but requires sorted i
print("\nREFLECTION: Observed results match theoretical complexities. Recursive algorithms
```

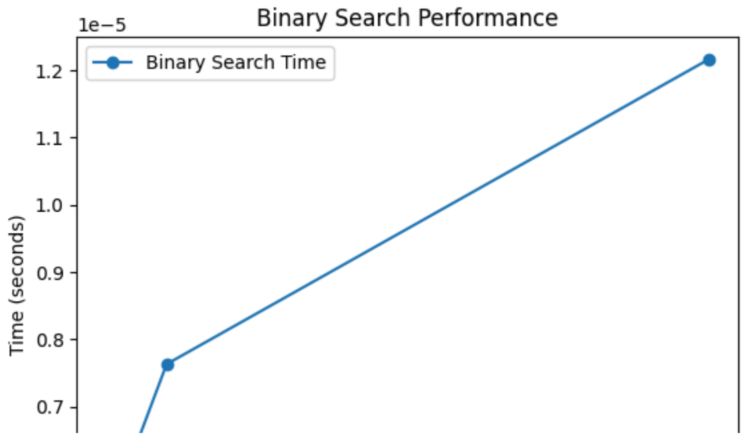

Sorting Algorithms Time Comparison
Merge Sort
Quick Sort
Insertion Sort
Bubble Sort
Selection Sort
Time (seconds)
0.00
0.05
0.10
0.15
0.20
250
500
750
1000
1250
1500
1750
2000
Input Size (n)

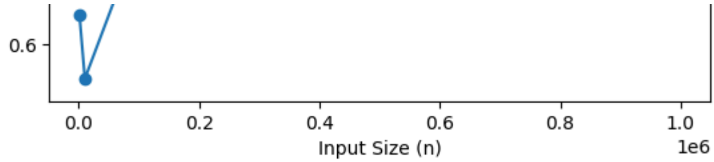

Sorting Algorithms Memory Comparison
Merge Sort
Quick Sort
Insertion Sort
Bubble Sort
Selection Sort
Memory (MB)
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
250
500
750
1000
1250
1500
1750
2000
Input Size (n)

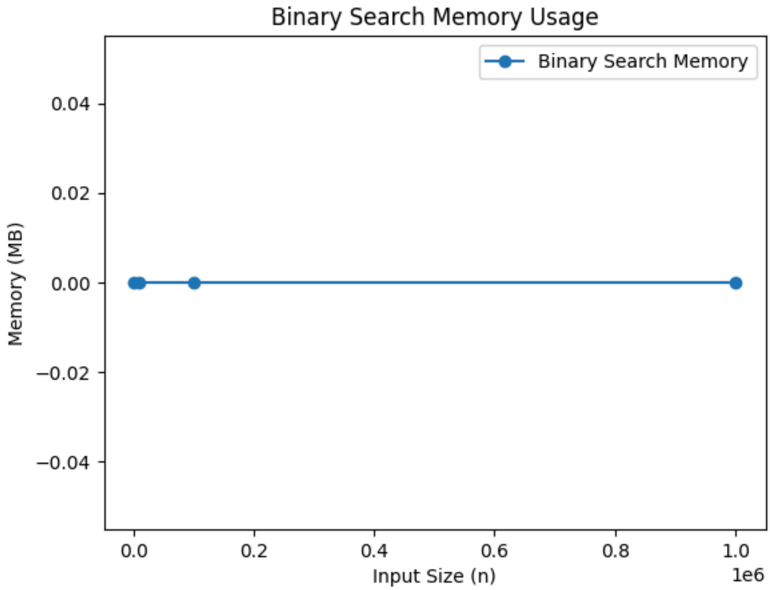

Fibonacci Time Comparison
Recursive Fibonacci (Time)
DP Fibonacci (Time)
0.150
0.125


Time (seconds)
0.100
0.075
0.050
0.025
0.000
5
10
15
20
25
30
n


Fibonacci Memory Comparison
Recursive Fibonacci (Mem)
DP Fibonacci (Mem)
Memory (MB)
0.025
0.020
0.015
0.010
0.005
0.000
5
10
15
20
25
30
n


Binary Search Performance
1e−5
Binary Search Time
Time (seconds)
1.2
1.1
1.0
0.9
0.8
0.7






```
Algorithm            Best         Average      Worst        Space
---------------------------------------------------------------------
Fibonacci Recursive  -            -            O(2^n)       O(n)
Fibonacci DP         O(n)         O(n)         O(n)         O(1)
Merge Sort           O(n log n)   O(n log n)   O(n log n)   O(n)
Quick Sort           O(n log n)   O(n log n)   O(n^2)       O(log n)
Insertion Sort       O(n)         O(n^2)       O(n^2)       O(1)
Bubble Sort          O(n)         O(n^2)       O(n^2)       O(1)
Selection Sort       O(n^2)       O(n^2)       O(n^2)       O(1)
Binary Search        O(1)         O(log n)     O(log n)     O(1)

EXPERIMENTAL SUMMARY (Sorting Algorithms):
   Input Size  Merge Sort Time  Quick Sort Time  Insertion Sort Time  \
0        1000         0.000206         0.000146             0.000173
1       10000         0.000906         0.000781             0.005794
2      100000         0.001959         0.001525             0.022294
3     1000000         0.004177         0.003201             0.108711

   Bubble Sort Time  Selection Sort Time  Merge Sort Mem  Quick Sort Mem  \
0          0.000364             0.000188        0.203125        0.140625
1          0.011083             0.005583        0.000000        0.003906
2          0.048071             0.023355        0.011719        0.003906
3          0.204898             0.098438        0.000000        0.003906

   Insertion Sort Mem  Bubble Sort Mem  Selection Sort Mem
0                 0.0              0.0                 0.0
1                 0.0              0.0                 0.0
2                 0.0              0.0                 0.0
3                 0.0              0.0                 0.0
```

```
✅ SUMMARY & INSIGHTS
- Fibonacci Recursive is extremely slow for large n (stack depth risk).
- Fibonacci DP is fast and memory efficient.
- Merge Sort and Quick Sort are efficient O(n log n) sorts, though Merge uses more mem
- Insertion, Bubble, Selection are O(n^2), impractical beyond small n.
- Binary Search is very efficient O(log n), negligible memory, but requires sorted inp

REFLECTION: Observed results match theoretical complexities. Recursive algorithms risk
```