DSA Lab
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Experiment No.: 8

AIM:
The aim of this experiment is to implement and execute the Insertion Sort and Merge Sort algorithms and subsequently analyze their time complexity.

THEORY:
Insertion Sort:
Algorithm Overview:
Insertion Sort is a simple sorting algorithm that builds the final sorted array one element at a time. It is much less efficient on large lists than more advanced algorithms such as quicksort, heapsort, or merge sort. However, insertion sort provides several advantages in its simplicity and ease of implementation.

Time Complexity Analysis:
Worst-Case Time Complexity (O(n^2)): The worst-case time complexity occurs when the array is in reverse order. In each iteration, the algorithm compares and shifts elements, leading to quadratic time complexity.

Best-Case Time Complexity (O(n)): The best-case time complexity occurs when the array is already sorted. In this scenario, insertion sort makes minimal comparisons, resulting in linear time complexity.

Average-Case Time Complexity (O(n^2)): On average, insertion sort exhibits quadratic time complexity, making it less suitable for large datasets.

Merge Sort:

Algorithm Overview:

Merge Sort is a divide-and-conquer algorithm that recursively divides the input array into two halves, sorts each half, and then merges the sorted halves. It ensures stability and guarantees a time complexity of O(n log n).

Time Complexity Analysis:

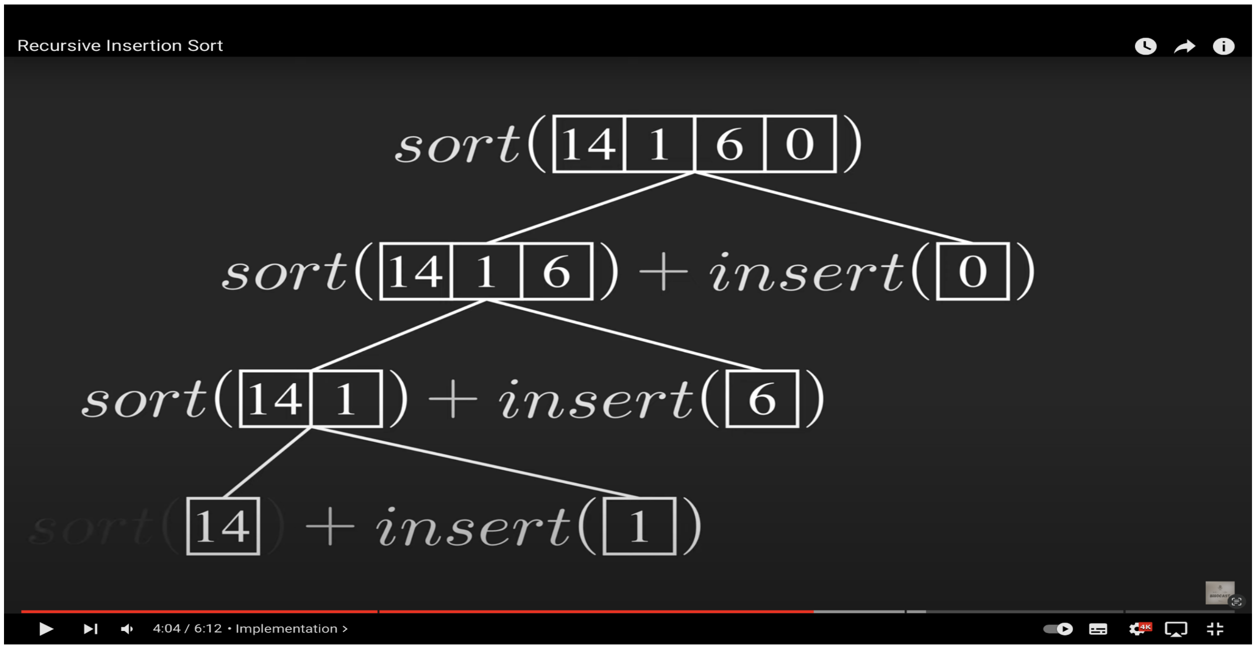
Worst-Case Time Complexity (O(n log n)): The worst-case time complexity of merge sort is O(n log n), making it efficient for large datasets. The algorithm consistently divides the array into halves until individual elements, and then merges them in a sorted manner.

Best-Case Time Complexity (O(n log n)): The best-case time complexity is also O(n log n). Unlike other algorithms, merge sort's performance is consistent across different scenarios.

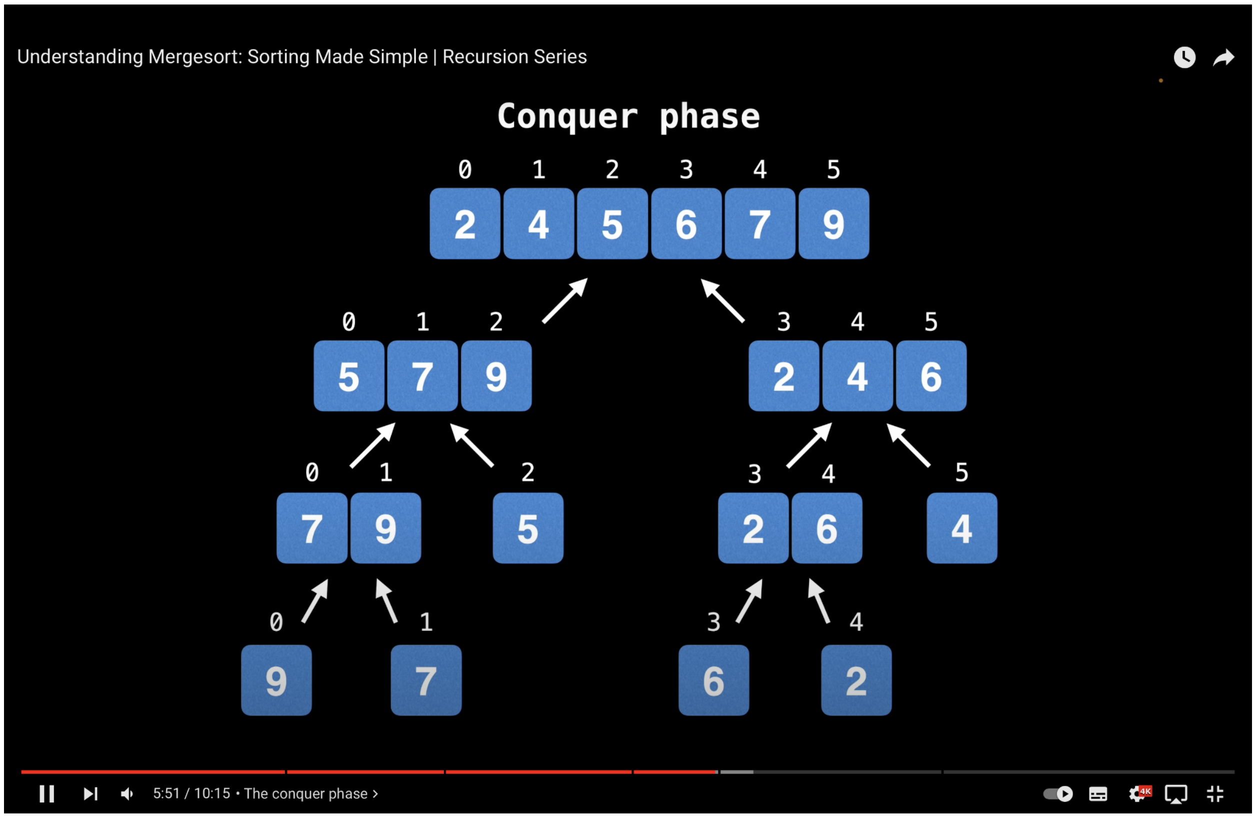
Average-Case Time Complexity (O(n log n)): Merge sort maintains its O(n log n) time complexity on average, making it a reliable choice for sorting.

EXAMPLE:

Insertion Sort:


Recursive Insertion Sort
$sort(\boxed{14}\boxed{1}\boxed{6}\boxed{0})$
$sort(\boxed{14}\boxed{1}\boxed{6}) + insert(\boxed{0})$
$sort(\boxed{14}\boxed{1}) + insert(\boxed{6})$
$sort(\boxed{14}) + insert(\boxed{1})$
4:04 / 6:12 • Implementation ›

Merge Sort:


Understanding Mergesort: Sorting Made Simple | Recursion Series
Conquer phase
0 1 2 3 4 5
2 4 5 6 7 9
0 1 2
5 7 9
3 4 5
2 4 6
0 1
7 9
2
5
3 4
2 6
5
4
0
9
1
7
3
6
4
2
5:51 / 10:15 • The conquer phase ›

ALGORITHM:

```
Step 0: Insert_sort(array)
            int j;
            int i;
            int key;
            while(j<length of array)
                key = array(j)
                i=j-1
                if(i>=0 && array(i)>key)
                   array(i+1)=array(i)
                   i=i-1;
           array(i+1)=key

Step 1: merge_sort(A,p,r)
           if p<r
           q=[(p+r)/2]
           Merge_sort(A,p,q)
           Merge_sort(A,q+1,r)
           Merge(A,p,q,r)

Step 2: merge(A,p,q,r)
           n1 = q-p+1
           n2 = r-q
           Let L(1,....n1+1] and R[1……n2+1] be new arrays

           for(i = 1 to n)
                L[i] = A[p+i - 1]

Step 3: printarray(array)
            print(array)

Step 4: Open file(data.txt)
            Put start and end time when the functions are called in the int main.
            cout the time that is taken by merge and insertion sort in the file.
```

Step 5: To plot graph to see the time complexities between merge and insertion sort, we use matplotlib in python.

```
import matplotlib.pyplot as plt
plt.plot(num,time_ins,'b',label="Insertion-sort")
plt.plot(num,time_merge,'r',label="Merge-sort")
plt.legend()
```

CONCLUSION:

In conclusion, while both Insertion Sort and Merge Sort aim to sort arrays, their time complexity characteristics differ significantly. Insertion Sort, with its quadratic time complexity, is suitable for small datasets, while Merge Sort, with its consistent O(n log n) time complexity, excels in handling larger datasets. The empirical analysis of their time complexity through experimental execution will provide valuable insights into their practical performance characteristics.

CODE:

```
#include <bits/stdc++.h>

using namespace std;

void insert_sort(int *p, int n)
{
        int i;
        //int j=0;
        int key;
        for(int j=1; j<n;j++)
        {
        key=p[j];
        i=j-1;

        while(i>=0 && p[i]>key)
        {
```

```
        p[i+1]=p[i];
        i=i-1;
        }

        p[i+1]=key;
        }
}

void merge(int *arr, int p, int q, int r) {

  int n1 = q - p + 1;
  int n2 = r - q;

  int L[n1], M[n2];

  for (int i = 0; i < n1; i++)
        L[i] = arr[p + i];
  for (int j = 0; j < n2; j++)
        M[j] = arr[q + 1 + j];


  int i, j, k;
  i = 0;
  j = 0;
  k = p;


  while (i < n1 && j < n2) {
        if (L[i] <= M[j]) {
        arr[k] = L[i];
        i++;
        } else {
        arr[k] = M[j];
        j++;
        }
        k++;
  }
  while (i < n1) {
        arr[k] = L[i];
        i++;
        k++;
  }

  while (j < n2) {
        arr[k] = M[j];
        j++;
        k++;
  }
}


void mergeSort(int *arr, int l, int r) {
  if (l < r) {

        int m = l + (r - l) / 2;

        mergeSort(arr, l, m);
        mergeSort(arr, m + 1, r);


        merge(arr, l, m, r);
  }
}


void printArray(int *arr, int size) {
  for (int i = 0; i < size; i++)
        cout << arr[i] << " ";
  cout << endl;
}
```

```
int main()
{
        ofstream file;
        file.open("data.txt");

        int input[8] = {100,1000, 5000, 10000, 50000, 70000, 100000, 120000};

        for(int i=0; i<8; i++){


        time_t start , end, start1, end1;

        // int n;
        // cout<<"Enter the size of array: ";
        // cin>>n;
        int arr[input[i]];
        int arr1[input[i]];
        //cout<<"Enter the elements"<<endl;


        for(int k =input[i]; k>0; k--)
        {
        arr[input[i]-k]=k;
        }

        for(int j =input[i]; j>0; j--)
        {
        arr1[input[i]-j]=j;
        }

        cout<<"Using insertion sort:"<<endl;
        time(&start);
        ios_base::sync_with_stdio(false);

        insert_sort(arr,input[i]);
        time(&end);
        printArray(arr, input[i]);

        double time_taken = double(end - start);
        file << "Insertion sort ->  size = "<<input[i]<<",       time : " << fixed
        << time_taken << setprecision(5);
        file << " sec " << endl;

        cout<<"Using Merge sort:"<<endl;

        time(&start1);
        ios_base::sync_with_stdio(false);

        mergeSort(arr1, 0, input[i] - 1);
        time(&end1);

        printArray(arr1, input[i]);

        double time_taken1 = double(end1 - start1);
        file << "Merge sort          ->  size = "<<input[i]<<",  time : " << fixed
        << time_taken1 << setprecision(5);
        file << " sec " << endl;
        // file<<input[i];

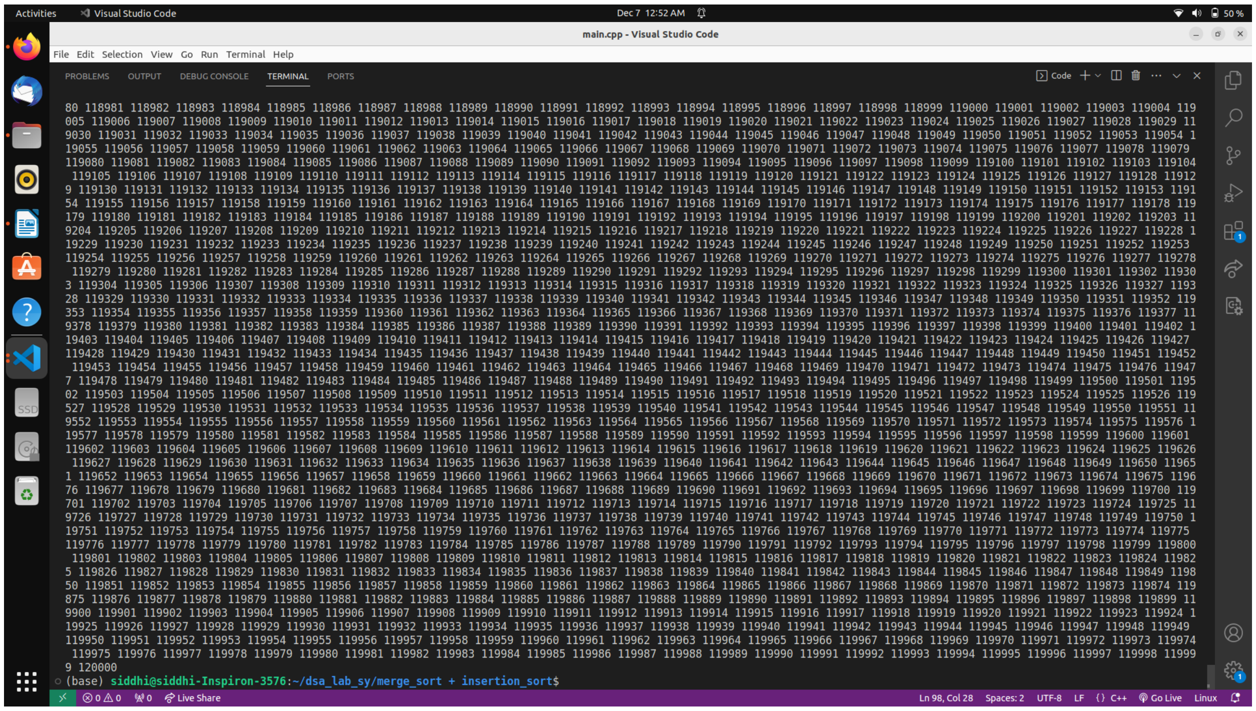
        }





        return 0;
}
```

OUTPUT:



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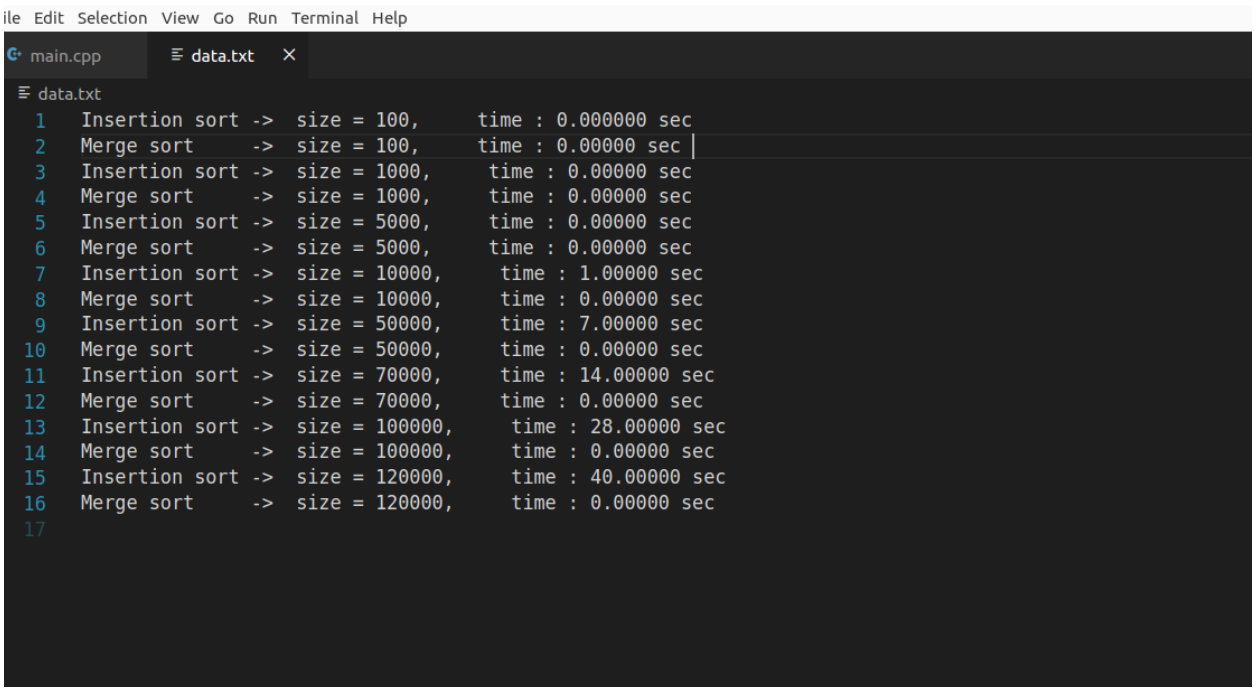
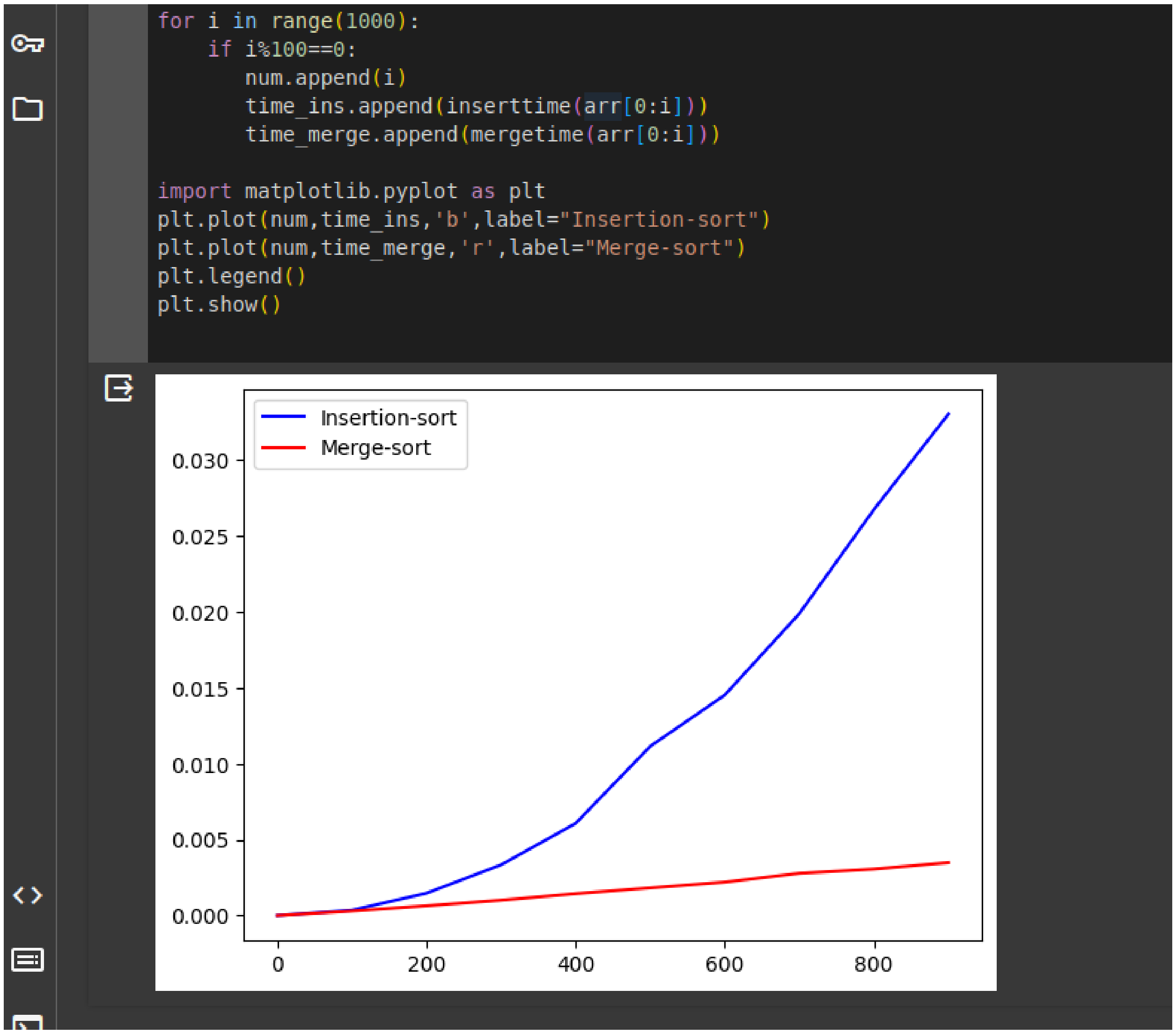
9 120000
(base) siddhi@siddhi-Inspiron-3576:~/dsa_lab_sy/merge_sort + insertion_sort$
```

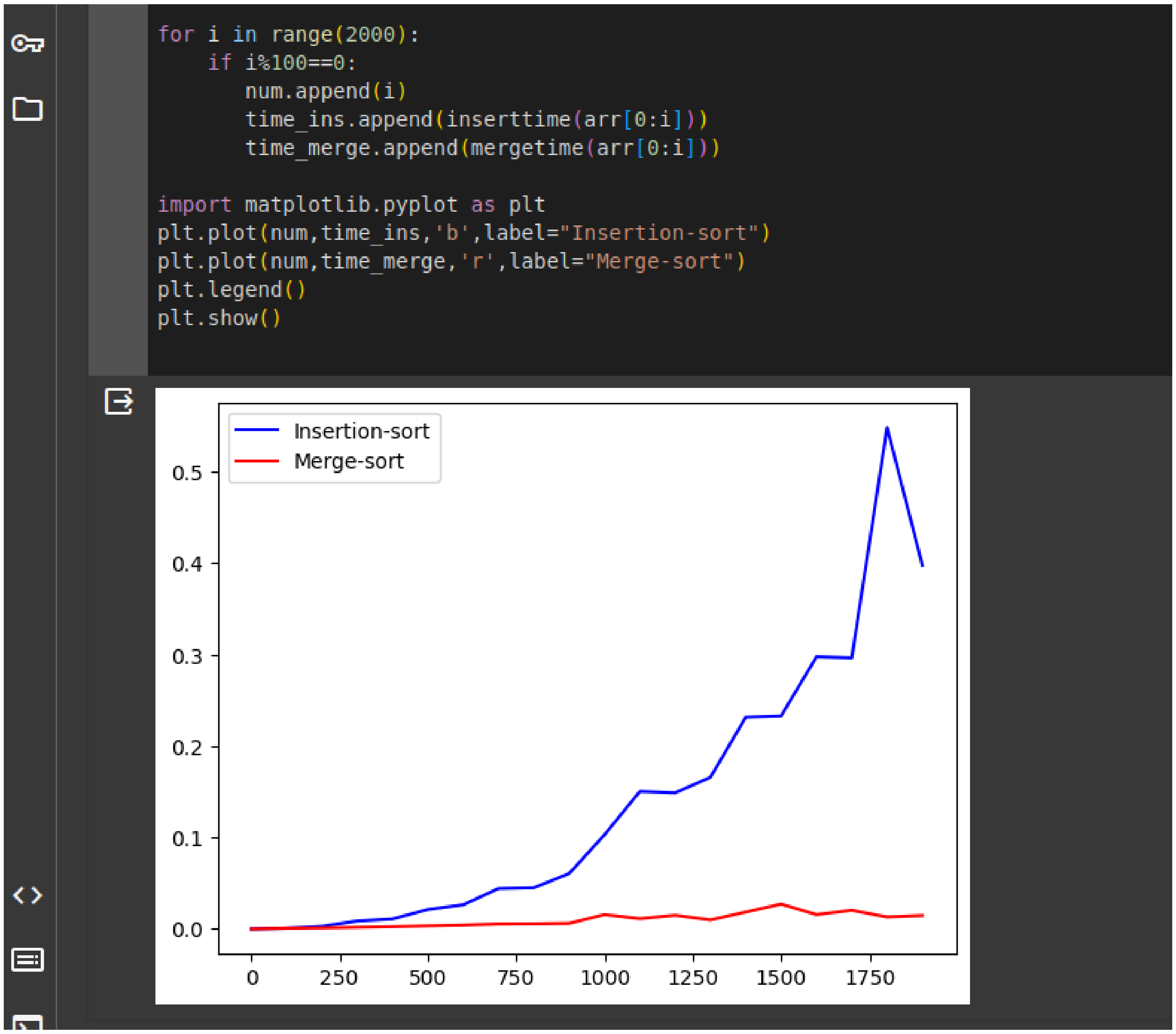


```
Insertion sort -> size = 100,     time : 0.000000 sec
Merge sort     -> size = 100,     time : 0.00000 sec
Insertion sort -> size = 1000,     time : 0.00000 sec
Merge sort     -> size = 1000,     time : 0.00000 sec
Insertion sort -> size = 5000,     time : 0.00000 sec
Merge sort     -> size = 5000,     time : 0.00000 sec
Insertion sort -> size = 10000,     time : 1.00000 sec
Merge sort     -> size = 10000,     time : 0.00000 sec
Insertion sort -> size = 50000,     time : 7.00000 sec
Merge sort     -> size = 50000,     time : 0.00000 sec
Insertion sort -> size = 70000,     time : 14.00000 sec
Merge sort     -> size = 70000,     time : 0.00000 sec
Insertion sort -> size = 100000,     time : 28.00000 sec
Merge sort     -> size = 100000,     time : 0.00000 sec
Insertion sort -> size = 120000,     time : 40.00000 sec
Merge sort     -> size = 120000,     time : 0.00000 sec
```



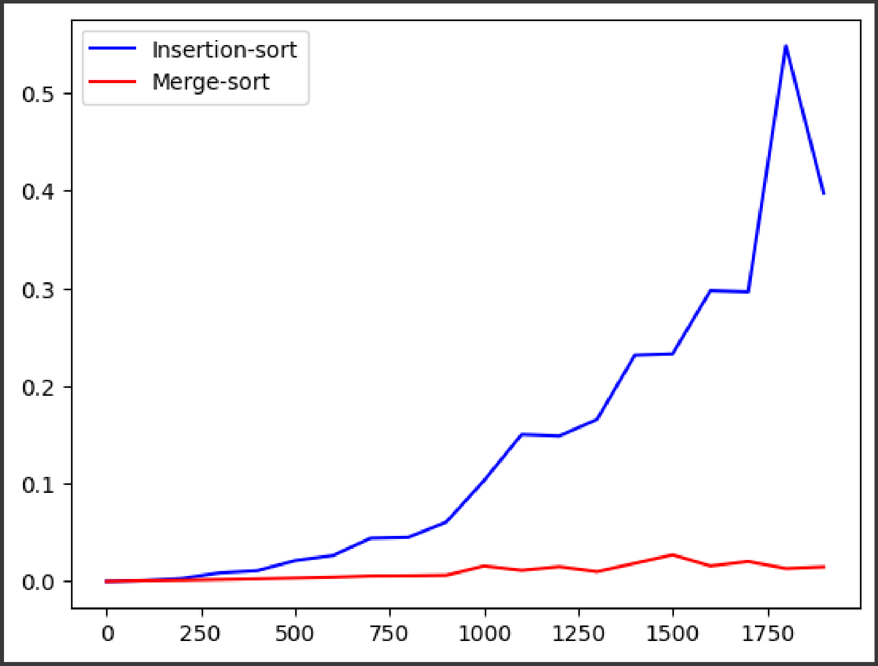
```
for i in range(1000):
    if i%100==0:
       num.append(i)
       time_ins.append(inserttime(arr[0:i]))
       time_merge.append(mergetime(arr[0:i]))

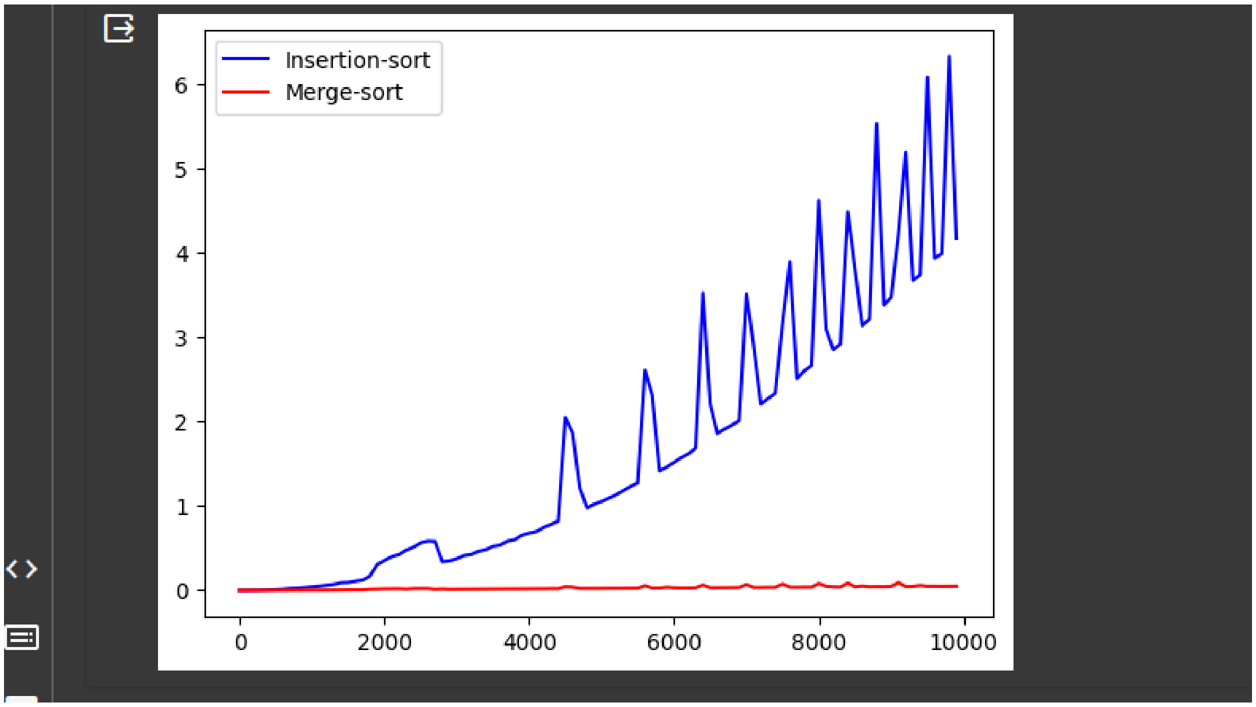
import matplotlib.pyplot as plt
plt.plot(num,time_ins,'b',label="Insertion-sort")
plt.plot(num,time_merge,'r',label="Merge-sort")
plt.legend()
plt.show()
```



```
for i in range(2000):
    if i%100==0:
       num.append(i)
       time_ins.append(inserttime(arr[0:i]))
       time_merge.append(mergetime(arr[0:i]))

import matplotlib.pyplot as plt
plt.plot(num,time_ins,'b',label="Insertion-sort")
plt.plot(num,time_merge,'r',label="Merge-sort")
plt.legend()
plt.show()
```




Insertion-sort
Merge-sort
0
1
2
3
4
5
6
0
2000
4000
6000
8000
10000