Gebze Technical University
Computer Engineering

CSE 222 - 2018 Spring

HOMEWORK 5 REPORT

CENGİZ TOPRAK
161044087

Course Assistant:
FATMA NUR ESİRCİ

1 Double Hashing Map

This part about Question1 in HW5

1.1 Pseudocode and Explanation

Code of get method:

```
public Object get(Object key) {
    int index = key.hashCode();
    int temp;
    if (index < 0) index *= -1;
    index %= table.length;
    temp = index;
    while (true) {
        if (table[index] != null && !table[index].getState()
                                 && table[index].getKey().equals(key))
            return table[index].getValue();
        index = (index + 1)%table.length;
        if (index == temp) return null;
    }
}
```

Pseudocode for get method:

```
Object get(Object key):

1-) Set index to key.hashCode()

2-) if index < 0

      multiply index to mines 1

3-)set temp to index

4-) if table[index] != null and table[index] != deleted and key ==
                                        table[index].getKey() do


      return table[index].getValue()

5-) Set index to (index + 1) % length of table

6-) if index == temp do

      return null

7-) repeat 4-6 steps
```

```

```

```
Pseudocode for get mehod:

Object put(Object key, Object value):

1-) Decleare variables index,newIndex,hash2,i and initialize them.

2-) Set index to key.hashCode.

3-) if index < 0 do

      multiply index to mines 1

4-) Set index to (index + 1)% size of table

5-) call IsRequiredRehash() function check return value.

6-) if return value == true do

      call rehash()

7-) if table[index].getKey() == null do

      create a new entry that has key and value

      set table[index] to this created entry

      increase numbers of items in the table by one and

      return table[index].getValue()

8-) else if  table[index].getKey() == key do

      update value by setting new value and return old value.

9-) call doubleHash(index) and assign return value of it to hash2 variable.

10-) Set newIndex to(index + i*hash2)% size of table

11-) if table[newIndex].getKey() == null do

      create a new entry that has key and value

      set table[newindex] to this created entry

      increase numbers of items in the table by one and

      get out loop using break keyword.

12-) increase i by one

13-) repeat 10-12 steps

14-) return value of table[newIndex].getValue()
```

```
IsRequiredRehash():---> Check wheather is required rehash or not

rehash():--->increase size of table to proper size and insert all elements into
table properly.

doubleHash(index):--->decrease collisions by second hashing.
```

Code of put method:

```
public Object put(Object key, Object value) {
    int index =  key.hashCode();
    int hash2,i = 0;
    int newIndex = 0;
    if (index < 0) index *= -1;
    index = index % table.length;
    System.out.printf("Index : %d Key : %s\n",index,key.toString());
    if (IsRequiredRehash()) {
        rehash();
    }
    if (table[index] == null) {
        table[index]=new Entry(key,value,false);
        ++numbersOfItems;
        return table[index].getValue();
    }
    else if (table[index].getKey().equals(key)){
        Object oldValue = table[index].getValue();
        table[index].setValue(value);
        return oldValue;
    }
    hash2 = doubleHash(index);
    while (true) {
        newIndex = (index + i*hash2)%table.length;
        if (table[newIndex] == null) {
            table[newIndex] = new Entry(key,value,false);
            ++numbersOfItems;
            break;
        }
        ++i;
    }
    return  table[newIndex].getValue();
}
```

Pseudocode for remove method:

```
Object remove(Object key):

1-) Decleare variable index,temp and initialize them.

2-) Set index to key.hashCode()

3-) if index is negative do

      multiply index to mines one

4-) Set index to index by modula length of table.

5-) Set temp to index.
```

```
6-) if key == table[index].getKey() do
    decleare variable value
    set value to table[index].getValue()
    set table[index] to deleted
    increase number of deleteted items by one
    decrease number of undeleted items by one
    return taken value
7-) Set index to (index plus one) by modula length of table
8-) if index == temp do (All table iterate and item is not found)
       return null
9-) if table[index] != null and table[index] != deleted and
       key == table[index].getKey() do
            decleare variable value
            set value to table[index].getValue()
            set table[index] to deleted
            increase number of deleteted items by one
            decrease number of undeleted items by one
            return taken value
10-) repeat 7-9 steps
```

Code for remove method:

```
public Object remove(Object key) {
    int index = key.hashCode();
    int temp;
    if (index < 0) index *= -1;
    index %= table.length;
    temp = index;
    if (table[index].getKey().equals(key)) {
        Object value = table[index].getValue();
        table[index].setState(true);
        ++numberOfDeletedItems;
        --numbersOfItems;
        return value;
    }
    while (true) {
        if ((index = (index + 1) % table.length) == temp) return null;
        if (table[index] != null && !table[index].getState()
                                 &&  table[index].getKey().equals(key)) {
            Object value = table[index].getValue();
            table[index].setState(true);
            ++numberOfDeletedItems;
            --numbersOfItems;
            return value;
        }
    }
}
```

In implementation of double hashing map used java map interface and enrty class from course textbook.It is implemented just remove,add,get,size,Isempty and containsKey methods from map interface

```
Index : 8 Key : Jack Table size : 19
Index : 12 Key : George Table size : 19
Index : 1 Key : Victory Table size : 19
Collision occurs:
Index : 8 New Index : 0 Key : Jennifer Table size : 19
Index : 14 Key : Hector Table size : 19
Collision occurs:
Index : 14 New Index : 5 Key : Richard Table size : 19
Index : 10 Key : Teresa Table size : 19
Collision occurs:
Index : 14 New Index : 15 Key : Pillow Table size : 19
Collision occurs:
Index : 1 New Index : 18 Key : Frank Table size : 19
Index : 16 Key : David Table size : 19
Collision occurs:
Index : 1 New Index : 17 Key : Edward Table size : 19
Collision occurs:
Index : 10 New Index : 9 Key : Elisabet Table size : 19
Index : 2 Key : Baron Table size : 19
Index : 38 Key : Jennifer Table size : 41
Index : 5 Key : Victory Table size : 41
Index : 15 Key : Baron Table size : 41
Index : 34 Key : Richard Table size : 41
Index : 7 Key : Jack Table size : 41
Index : 0 Key : Elisabet Table size : 41
Index : 26 Key : Teresa Table size : 41
Index : 20 Key : George Table size : 41
Index : 21 Key : Hector Table size : 41
Collision occurs:
Index : 0 New Index : 19 Key : Pillow Table size : 41
Index : 6 Key : David Table size : 41
Index : 14 Key : Edward Table size : 41
Index : 2 Key : Frank Table size : 41
Prime : 37 Size : 41
Index : 13 Key : Alexis Table size : 41
```

0	K:Jennefer V:	collusion occurs(normal index=8) hash2 = doubleHash(index) = 11 doubleHash(index)=prime – (index%prime) where prime=19 formula for each collusion index=(index + i*hash2)%19 where i initialize zero and increase value of it by one when each collusion occurs in a while loop index=(8 +0*11)%19 = 8 collusion occurs , increase i by one index=(8 +1*11)%19 = 0 no collusion add key to table[0] break loop.
1	K:Victory V:	key:Victory 1=index=key.hashCode()%19(jack added 1.inedexed cell)
2	K:Baron V:	key:Baron 2=index=key.hashCode()%19(jack added 2.inedexed cell)
3		
4		
5	K:Richard V:	collusion occurs(normal index 14) perform operation like 0.indexed table cell.
6		
7		
8	K:Jack V:	key:Jack 8=index = key.hashCode()%19(jack added 8.inedexed cell)
9	K:Elisabet V:	collusion occurs(normal index 10) perform operation like 0.indexed table cell.
10	K:Teresa V:	key:Teresa 10=index=key.hashCode()%19(Teresa added 10.inedexed cell)
11		
12	K:George V:	key:George 12=index=key.hashCode()%19(George added 12.inedexed cell)
13		
14	K:Hector V:	key:George 14=index=key.hashCode()%19(George added 14.inedexed cell)
15	K:Pillow V:	collusion occurs(normal index 14) perform operation like 0.indexed table cell.
16	K:David V:	key:David 16=index = key.hashCode()%19(David added 16.inedexed cell)
17	K:Edward V:	collusion occurs(normal index 1) perform operation like 0.indexed table cell.
18	K:Frank V:	collusion occurs(normal index 1) perform operation like 0.indexed table cell.

Check whetaher rehash is required or not.
LOAD FACTOR:0.65
table size : 19
number of items in the table :13
13/19 = 0.68
since it exceeds load factor it is needed to rehash table.
It is grown table size to a number which this number is smaller prime number that is bigger than 2* sizeoftable + 1.
new size >= 2*19 + 1>=39
new size = 41
After that all elements in the old table is added to new table properly.

second table

```
Index : 6 Key : Henry Table size : 11
Index : 9 Key : Hercule Table size : 11
Collision occurs:
Index : 6 New Index : 7 Key : Austin Table size : 11
Index : 4 Key : Beckham Table size : 11
Collision occurs:
Index : 6 New Index : 8 Key : Camber Table size : 11
Collision occurs:
Index : 6 New Index : 10 Key : Darwin Table size : 11
Collision occurs:
Index : 10 New Index : 3 Key : Elberta Table size : 11
Collision occurs:
Index : 3 New Index : 0 Key : Fletcher Table size : 11
Index : 11 Key : Fletcher Table size : 23
Index : 1 Key : Elberta Table size : 23
Index : 15 Key : Beckham Table size : 23
Index : 14 Key : Henry Table size : 23
Collision occurs:
Index : 11 New Index : 17 Key : Austin Table size : 23
Index : 6 Key : Camber Table size : 23
Index : 3 Key : Hercule Table size : 23
Index : 21 Key : Darwin Table size : 23
Prime : 19 Size : 23
Index : 5 Key : Garrison Table size : 23
Index : 2 Key : Davidson Table size : 23
Collision occurs:
Index : 15 New Index : 19 Key : Edward Table size : 23
Collision occurs:
Index : 6 New Index : 9 Key : Chancellor Table size : 23
Collision occurs:
Index : 15 New Index : 0 Key : Baron Table size : 23
Index : 22 Key : Ebony Table size : 23
```

0	K:Fletcher V:	collusion occurs(normal index 3) perform operation like 7.indexed table cell
1		
2		
3	K:Elberta V:	collusion occurs(normal index 10) perform operation like 7.indexed table cell
4	K:Beckham V:	key: Beckham 4 = index = key.hashCode()%11(Beckham added 4.inedexed cell)
5		
6	K:Henry V:	key:Henry 6 = index = key.hashCode()%11(Henry added 6.inedexed cell)
7	K:Austin V:	collusion occurs(normal index = 6) hash2 = doubleHash(index) = 1 doubleHash(index)=prime – (index%prime) where prime=7 formula for each collusion index=(index + i*hash2)%11 where i initialize zero and increase value of it by one when each collusion occurs in a while loop index=(6 +0*1)%11 = 6 collusion occurs , increase i by one index=(6 +1*1)%11 = 7 no collusion add key to table[0] break loop.
8	K:Camber V:	collusion occurs(normal index 6) perform operation like 7.indexed table cell
9	K:Hercule V:	key:Hercule 9 = index = key.hashCode()%11(Hercule added 9.inedexed cell)
10	K:Darwin V:	collusion occurs(normal index 6) perform operation like 7.indexed table cell

Check whetaher rehash is required or not.
LOAD FACTOR:0.65
table size : 11
number of items in the table :8
8/11 = 0.72
since it exceeds load factor it is needed to rehash table.
It is grown table size to a number which this number is smaller prime number that is bigger than 2* sizeoftable + 1.
new size >= 2*11 + 1>=23
new size = 23
After that all elements in the old table is added to new table properly.

2 Recursive Hashing Set

2.1 Pseudocode and Explanation

Code for contains method:

```
public boolean contains(Object o) {
    E obj = (E)o;
    int hashcode = obj.hashCode();
    if (hashcode < 0) hashcode *= -1;
    return containsHelper(table,hashcode,obj);
}
```

Pseudocode for contains method:

```
boolean contains(Object o):
1-) cast object to type E and declare variable ojb and set obj to casted value
2-) decleare hashcode and set to  obj.hashCode()
3-) if hashcode < 0 do
       make hashcode positive
4-) call containsHelper parameters with table,hashcode,obj and
    return value of calling function.
```

Code for contains method:

```
private boolean containsHelper(Node<E>[] array,int hashcode,E target) {
    if (array == null) return false;
    int index = hashcode % array.length;
    if (array[index] != null && array[index].getElement().equals(target))
            return true;
    return containsHelper(array[index].getTable(),hashcode,target);
}
```

Pseudocode for containsHelper :

```
boolean containsHelper(Node<E>[] array,int hashcode,E target) {
1-) if array == null do
       return false
2-) decleare variable index and set index to hashcode % size of array
3-) if array[index] != null and array[index].getElement() == target do
       return true
4-) call containsHelper parameters with table.getTable(),hashcode,obj and
    return value of calling function.
```

Pseudocode for add method:

```
public boolean add(Object o) {
1-) cast object to type E and declare variable ojb and set obj to casted value
2-) decleare hashcode and set to  obj.hashCode()
3-) if hashcode < 0 do
       make hashcode positive
4-) decleare variable index and set index to hashcode % length of table;
5-) call addHelper parameters with table,table.length,index,hashcode,obj and
    return value of calling function.
```

Code for add method:

```
boolean add(Object o) {
    E obj = (E)o;
    int hashcode = obj.hashCode();
    if (hashcode < 0) hashcode *= -1;
    int index = hashcode%table.length;
    return addHelper(table,table.length,index,hashcode,obj);
}
```

Code for addHelper method:

```
private boolean addHelper(Node<E>[] array,int length,int
     originIndex,int hashcode,E target) {
    int index;
    index = hashcode % array.length;
    if (array[index] != null && array[index].getElement().equals(target))
        return false;
    else if (array[index] == null) {
        array[index] = new Node<>(target);
        ++numberOfItems;
        return true;
    }
    else if (array[index] != null && array[index].getTable() != null) {
        return
addHelper(array[index].getTable(),array.length,originIndex,hashcode,target);
    }
    else if (array[index].getTable() == null) {
        if (length < 1) array[index].createTable(1);
        else array[index].createTable(findPrime(length - 1,0));
        int newIndex = target.hashCode()%array[index].getTable().length;
        if ( newIndex < 0)  newIndex *= -1;
        array[index].getTable()[newIndex] = new Node<>(target);
        ++numberOfItems;
        return true;
    }
    return false;
}
```

PseudoCode for addHelper method:

```
private boolean addHelper(Node<E>[] array,int length,int
     originIndex,int hashcode,E target) {
1-) Decleare variable index;
2-) Set index to hashcode % size of array
3-) if array[index] != null and array[index].getElement() == target do
        return false;
4-) else if array[index] == null do
        array[index] <-- new Node<>(target);
        increase numberOfItems by one
        return true;
5-) else if array[index] != null and array[index].getTable() != null do
        call addHelper parameters with array[index].getTable(),array.length
        originIndex,hashcode,target and return value of called function.

6-) else if array[index].getTable() == null do
        if length < 1 do
            array[index].createTable(1);
        else do
            array[index].createTable(findPrime(length - 1,0));
        decleare variable newIndex
        newIndex <-- target.hashCode()%array[index].getTable().length;
        if newIndex < 0  do
            newIndex <-- newIndex * -1;
        array[index].getTable()[newIndex] <-- new Node<>(target);
        increase numberOfItems by one
        return true;
7-) return false;
```

Code for remove method:

```
public boolean remove(Object o) {
    E obj = (E)o;
    int hashcode = obj.hashCode();
    if (hashcode < 0) hashcode *= -1;
    return removeHelper(table,hashcode,obj);
}
```

Pseudocode for remove method:

```
boolean remove(Object o):
1-) cast object to type E and declare variable ojb and set obj to casted value
2-) decleare hashcode and set to  obj.hashCode()
3-) if hashcode < 0 do
       make hashcode positive
5-) call removeHelper parameters with table,hashcode,obj and
    return value of calling function.
```

Code for removeHelper method:

```
private boolean removeHelper(Node<E>[] array,int hashcode,E
     target) {
    if (array == null) return false;
    int index = hashcode % array.length;
    if (array[index] != null && array[index].getElement().equals(target)) {
        array[index] = null;
        --numberOfItems;
        return true;
    }
    if (array[index] != null)
        return removeHelper(array[index].getTable(),hashcode,target);
    return false;
}
```

Pseudocode for removeHelper:

```
private boolean removeHelper(Node<E>[] array,int hashcode,E
     target):
1-) if array == null do
       return false;
2-) decleare variable  index
3-) index <-- hashcode % array.length;
4-) if array[index] != null and array[index].getElement() == target do
        array[index] <-- null
        decrease numberOfItems by one
        return true
5-) if array[index] != null do
        call removeHelper parameters with table.getTable(),hashcode,target and
        return value of calling function.
6-) return false
```

In implementation of recursive hashing set is used java set interface and generic class that has generic item and an array of same type of Node class course.It is implemented just

remove,add,size,Isempty,contains methods from set interface and some useful helper methods named removeHelper,addHelper and contiansHelper

2.2 Test Cases

Original index : 2 original table size : 11 index : 2 item : Jack table size : 11
Original index : 6 original table size : 11 index : 6 item : George table size : 11
Original index : 7 original table size : 11 index : 7 item : Victory table size : 11
Original index : 1 original table size : 11 index : 1 item : Jennifer table size : 11
Original index : 6 original table size : 11 index : 4 item : Hector table size : 7
Original index : 10 original table size : 11 index : 10 item : Richard table size : 11
Original index : 1 original table size : 11 index : 1 item : Teresa table size : 7
Original index : 0 original table size : 11 index : 0 item : Pillow table size : 11
Original index : 10 original table size : 11 index : 6 item : Frank table size : 7
Original index : 3 original table size : 11 index : 3 item : David table size : 11
Original index : 9 original table size : 11 index : 9 item : Edward table size : 11
Original index : 5 original table size : 11 index : 5 item : Elisabet table size : 11
Original index : 8 original table size : 11 index : 8 item : Baron table size : 11
Original index : 6 original table size : 11 index : 3 item : Alexis table size : 7
Original index : 8 original table size : 11 index : 3 item : Caroline table size : 7
Original index : 7 original table size : 11 index : 6 item : Jacky table size : 7
Original index : 1 original table size : 11 index : 6 item : Banner table size : 7
Original index : 7 original table size : 11 index : 4 item : Culver table size : 7
Original index : 0 original table size : 11 index : 6 item : Denver table size : 7
Original index : 4 original table size : 11 index : 4 item : Eleanor table size : 11
Original index : 2 original table size : 11 index : 2 item : Forrest table size : 7
Original index : 8 original table size : 11 index : 2 item : Grayson table size : 7
Original index : 8 original table size : 11 index : 4 item : Harley table size : 7
Original index : 9 original table size : 11 index : 2 item : Hawthorne table size : 7
Original index : 7 original table size : 11 index : 0 item : Jefferson table size : 7
Original index : 2 original table size : 11 index : 5 item : Keaton table size : 7
Original index : 10 original table size : 11 index : 6 item : Kimberley table size : 7
Original index : 7 original table size : 11 index : 0 item : Perry table size : 7

As seen above when each collusion occurs table size decrease.

3 Sorting Algortihms

3.1 MergeSort with DoubleLinkedList

This part about Question3 in HW5

3.1.1 Pseudocode and Explanation

Code of sort method:

```
public static  void sort(LinkedList<Integer> arr, int left, int right) {
    if (left < right)
    {
        // Find the middle point
```

```
        int middlePoint = (left+right)/2;
        // Sort first and second halves
        sort(arr, left, middlePoint);
        sort(arr , middlePoint+1, right);
        // Merge the sorted halves
        merge(arr, left, middlePoint, right);
    }
}
```

Pseudocode for sort method:

```
sort(LinkedList<Integer> arr, int left, int right):
1-) if left < right do
        decleare variable middlepoint
        Set middlepoint to left plus right by over two
        call the itself with parameters ,in turn,arr,left,middlepoint
        call the itself with parameters ,in turn,arr,middlepoint + 1,right
        call merge function with parameters,in turn,arr,left,middlepoint,right
2-) else do nothing
```

Code for merge method:

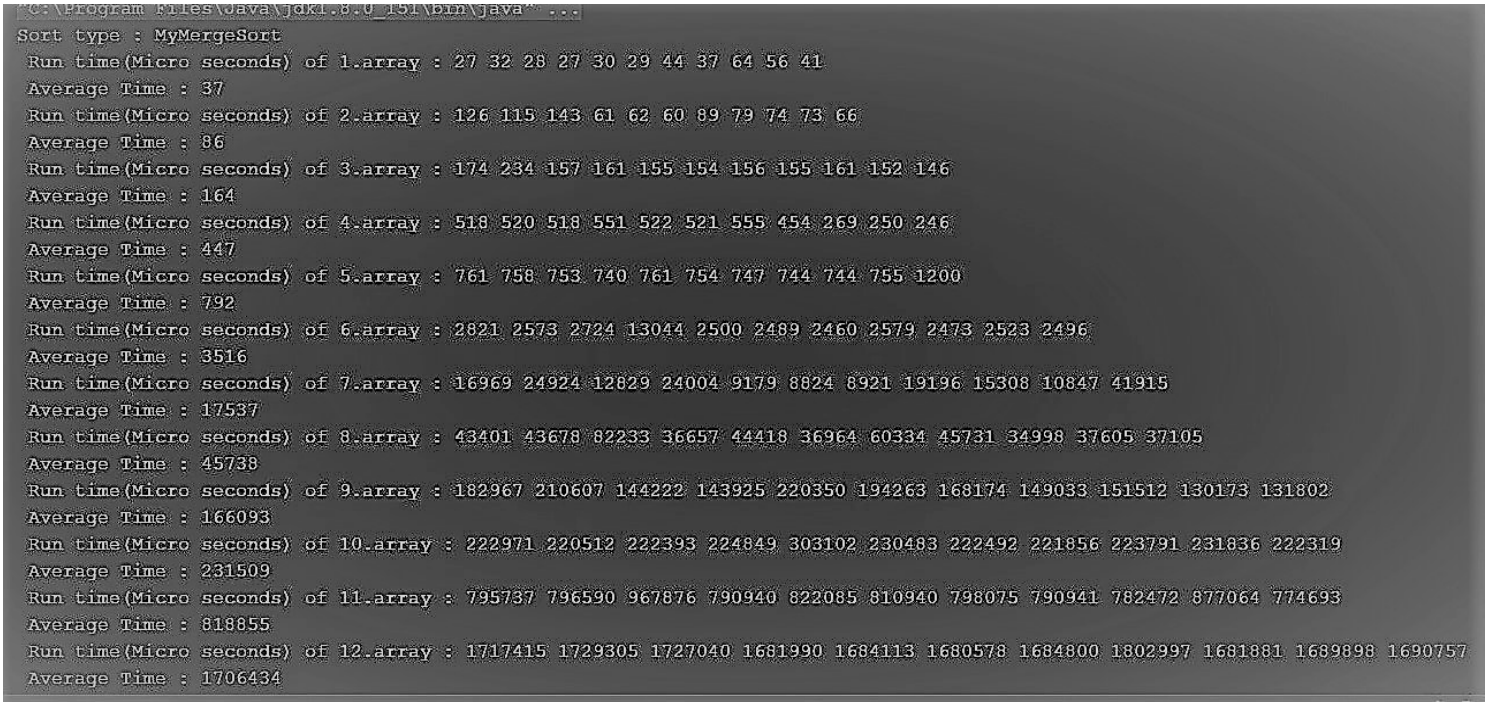
```
public static void merge (LinkedList<Integer> arr, int left, int middlePoint,
int right)
{

    int n1 = middlePoint - left + 1;
    int n2 = right - middlePoint;

    LinkedList<Integer> Left = new LinkedList<>();
    LinkedList<Integer> Right = new LinkedList<>();
    for (int i=0; i<n1; ++i)
        Left.add(arr.get(left + i));
    for (int j=0; j<n2; ++j)
        Right.add(arr.get(middlePoint + 1 + j));
    int i = 0, j = 0;
    int k = left;
    while (i < n1 && j < n2)
    {
        if (Left.get(i).compareTo(Right.get(j)) <= 0) {
            arr.set(k,Left.get(i));
            i++;
        }
        else {
            arr.set(k,Right.get(j));
            j++;
        }
```

```
        k++;
    }
    while (i < n1)
    {
        arr.set(k,Left.get(i));
        i++;
        k++;
    }
    while (j < n2)
    {
        arr.set(k,Right.get(j));
        j++;
        k++;
    }
}
```

Pseudocode for merge method:

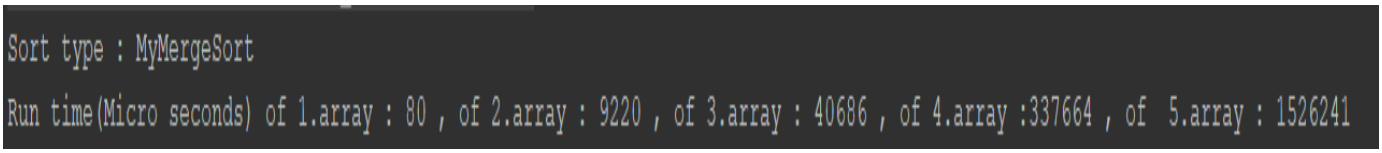
```
merge (LinkedList<Integer> arr, int left, int middlePoint, int right) :
1-) decleare n1 and n2 variables
2-) Set n1 to  middlePoint - left + 1 and n2 to  right - middlePoint
3-) decleare two LinkedList of Integer named left and right.
4-) allocate memory for both of them.
5-) for (int i=0; i<n1; ++i) do
      add arr.get(left + i) item to Left linkedList
6-) for (int j=0; j<n2; ++j) do
      add arr.get(middlePoint + 1 + j) item to Right LinkedList
7-) decleare two variables named i,j,k and i and j initialize to zero,
      and set k to left.
8-) while(i < n1 and j < n2) do
      if Left.get(i) < Right.get(j) do
         set k. indexed item in arr to Left.get(i) item
         increase i by one
      else do
         set k. indexed item in arr to Right.get(j) item
         increase j by one
      increase k by one
9-)  while (i < n1) do
          set k.indexed item in arr to  Left.get(i)
          increase i by one
          increase k by one
10-) while (j < n2) do
          set k.indexed item in arr to  Right.get(j)
          increase j by one
          increase k by one
```

3.1.2 Average Run Time Analysis



Since the above pictures is not enough clear ,I need to explain it.
Input sizes are ,in turn,20,40,100,200,400,800,1600,3200,4000,7000 and 10000.
Run time of merge sort with dll is reasonable up to 800 input size.In input size that is bigger than 1000, Run time of merge sort with dll is increasing much more and more ,and effiency of it is getting bad.Probably, time complexity of merge with dll is a bit bigger than nlogn.

3.1.3 Wort-case Performance Analysis



As seen above,run time of the worst case of merge sort with dll is increasing when input size is increase.Predictive of time complexity of it is bigger than nlogn.

3.2 MergeSort

3.2.1 Average Run Time Analysis

```
Sort type : MergeSort
 Run time(Micro seconds) of 1.array : 12 11 11 11 13 13 11 11 11 11 24
 Average Time : 12
 Run time(Micro seconds) of 2.array : 29 24 31 26 26 27 36 25 25 25 24
 Average Time : 27
 Run time(Micro seconds) of 3.array : 68 69 59 58 58 58 210 95 86 42 41
 Average Time : 76
 Run time(Micro seconds) of 4.array : 109 91 93 103 82 46 39 41 45 45 44
 Average Time : 67
 Run time(Micro seconds) of 5.array : 107 115 99 117 107 103 98 123 91 83 87
 Average Time : 102
 Run time(Micro seconds) of 6.array : 194 190 192 188 193 189 189 191 186 190 187
 Average Time : 189
 Run time(Micro seconds) of 7.array : 417 421 419 425 431 430 435 431 414 429 430
 Average Time : 425
 Run time(Micro seconds) of 8.array : 921 927 937 912 1061 941 932 741 716 725 2954
 Average Time : 1069
 Run time(Micro seconds) of 9.array : 6819 6570 6579 3749 3599 3805 3761 9566 3610 1590 6545
 Average Time : 5108
 Run time(Micro seconds) of 10.array : 7680 1861 1464 6427 8456 8390 1955 1556 8680 8287 8421
 Average Time : 5743
 Run time(Micro seconds) of 11.array : 1996 8593 9252 8593 9197 8694 8872 1926 1770 1733 1694
 Average Time : 5665
 Run time(Micro seconds) of 12.array : 4188 4168 4933 4269 3988 4089 4188 4410 3965 3960 3603
 Average Time : 4160
```

Input sizes are ,in turn,20,40,100,200,400,800,1600,3200,4000,7000 and 10000.
As seen above ,input size is getting increase ,avarage run time of merge sort increases with respect to nlog complexity ,generally.But since orderless of arrays is not same level , run time of array that has bigger input size maybe smaller than one that has smaller input size.

3.2.2 Wort-case Performance Analysis

```
Sort type : MergeSort
Run time(Micro seconds) of 1.array : 138 , of 2.array : 936 , of 3.array : 721 , of 4.array :2791 , of  5.array : 15468
```

Input sizes are ,in turn,100,1000,2000,5000 and 10000
Time complexity of this merge sort algorithm at the best case and worst case is O(nlogn).

3.3 Insertion Sort

3.3.1 Average Run Time Analysis

```
Sort type : InsertionSort
 Run time(Micro seconds) of 1.array : 3 3 3 3 2 3 2 3 3 2 3
 Average Time : 2
 Run time(Micro seconds) of 2.array : 11 8 8 8 7 8 14 9 7 8 8
 Average Time : 8
 Run time(Micro seconds) of 3.array : 32 30 30 32 30 30 31 31 31 30 24
 Average Time : 30
 Run time(Micro seconds) of 4.array : 51 51 48 58 54 49 48 49 48 48 49
 Average Time : 50
 Run time(Micro seconds) of 5.array : 199 199 199 198 199 198 198 199 199 199 199
 Average Time : 198
 Run time(Micro seconds) of 6.array : 664 663 1250 2673 2861 2671 2664 2744 2672 1629 122
 Average Time : 1873
 Run time(Micro seconds) of 7.array : 469 467 464 527 475 557 468 464 467 470 469
 Average Time : 481
 Run time(Micro seconds) of 8.array : 1794 1785 1834 1793 1785 1851 1821 1792 1784 1792 1838
 Average Time : 1806
 Run time(Micro seconds) of 9.array : 7297 7349 7278 7291 7394 7135 7194 7136 7207 7125 7176
 Average Time : 7234
 Run time(Micro seconds) of 10.array : 11780 11396 11532 11372 11441 12119 13301 13277 13663 13309 13282
 Average Time : 12406
 Run time(Micro seconds) of 11.array : 40728 41746 43537 40696 41059 43097 40678 41043 40543 44477 40649
 Average Time : 41659
 Run time(Micro seconds) of 12.array : 86339 84502 84187 94351 91692 84985 85172 84982 87879 86114 86153
 Average Time : 86941
```

Input sizes are ,in turn,20,40,100,200,400,800,1600,3200,4000,7000 and 10000.
As seen above ,input size is getting increase ,avarage run time of insertion sort increases with respect to n*n complexity.But since orderless of arrays is not same level , run time of array that has bigger input size maybe smaller than one that has smaller input size.(like input size 400 and 800).

3.3.2 Wort-case Performance Analysis

```
Sort type : InsertionSort
Run time(Micro seconds) of 1.array : 537 , of 2.array : 14379 , of 3.array : 42358 , of 4.array :35121 , of  5.array : 131419
```

Input sizes are ,in turn,100,1000,2000,5000 and 10000
Time complexity of this insertion sort algorithm at worst case is O(n*n).

3.4 Quick Sort

3.4.1 Average Run Time Analysis

```
Sort type : QuickSort
 Run time(Micro seconds) of 1.array : 8 7 7 7 8 7 7 7 11 8 7
 Average Time : 7
 Run time(Micro seconds) of 2.array : 16 17 31 22 18 17 20 17 18 17 27
 Average Time : 20
 Run time(Micro seconds) of 3.array : 45 56 45 45 55 46 67 164 49 49 51
 Average Time : 61
 Run time(Micro seconds) of 4.array : 161 161 160 157 159 161 148 158 153 138 143
 Average Time : 154
 Run time(Micro seconds) of 5.array : 331 163 97 98 100 105 100 113 70 72 71
 Average Time : 120
 Run time(Micro seconds) of 6.array : 178 150 96 97 95 96 95 94 117 95 95
 Average Time : 109
 Run time(Micro seconds) of 7.array : 214 215 215 214 215 216 217 263 379 313 213
 Average Time : 243
 Run time(Micro seconds) of 8.array : 482 481 484 488 492 489 652 762 791 768 772
 Average Time : 605
 Run time(Micro seconds) of 9.array : 1908 1700 1054 2258 4678 4131 4225 4124 4856 4274 4213
 Average Time : 3401
 Run time(Micro seconds) of 10.array : 1484 607 604 603 606 601 618 689 623 604 900
 Average Time : 721
 Run time(Micro seconds) of 11.array : 1602 1604 1759 1628 1603 1600 1610 1609 1618 1598 1631
 Average Time : 1623
 Run time(Micro seconds) of 12.array : 3652 3651 3649 3734 3651 3651 3661 3659 2734 2364 1906
 Average Time : 3301
```

Input sizes are ,in turn,20,40,100,200,400,800,1600,3200,4000,7000 and 10000.
As seen above ,input size is getting increase ,avarage run time of insertion sort increases with respect to n*logn complexity.But since orderless of arrays is not same level , run time of array that has bigger input size maybe smaller than one that has smaller input size.(like input size 4000 and 7000).

3.4.2 Wort-case Performance Analysis

```
Sort type : QuickSort
Run time(Micro seconds) of 1.array : 430 , of 2.array : 12228 , of 3.array : 32783 , of 4.array :79395 , of  5.array : 59398
```

Input sizes are ,in turn,100,1000,2000,5000 and 10000
Time complexity of this Quick sort algorithm at worst case is O(n*n).

3.5 Heap Sort

3.5.1 Average Run Time Analysis

```
Sort type : HeapSort
 Run time(Micro seconds) of 1.array : 7 6 6 10 6 6 6 6 15 8 9
 Average Time : 7
 Run time(Micro seconds) of 2.array : 17 27 22 21 21 22 21 21 21 21 21
 Average Time : 21
 Run time(Micro seconds) of 3.array : 52 52 52 54 52 53 52 52 52 52 52
 Average Time : 52
 Run time(Micro seconds) of 4.array : 165 141 121 108 105 106 106 106 106 106 105
 Average Time : 115
 Run time(Micro seconds) of 5.array : 248 402 392 393 392 407 634 610 615 613 387
 Average Time : 463
 Run time(Micro seconds) of 6.array : 568 555 555 554 553 554 553 554 554 555 554
 Average Time : 555
 Run time(Micro seconds) of 7.array : 597 521 440 426 425 439 464 426 453 428 425
 Average Time : 458
 Run time(Micro seconds) of 8.array : 931 929 1519 1525 1546 1345 1207 828 677 614 676
 Average Time : 1072
 Run time(Micro seconds) of 9.array : 1196 1848 2127 1907 1927 1262 1252 1240 845 850 788
 Average Time : 1385
 Run time(Micro seconds) of 10.array : 993 996 1073 834 829 830 828 832 879 838 829
 Average Time : 887
 Run time(Micro seconds) of 11.array : 1586 1581 1580 1580 1578 1584 1581 1630 1580 1576 1582
 Average Time : 1585
 Run time(Micro seconds) of 12.array : 2392 2393 2476 2489 2398 2397 2397 2403 2398 2501 2398
 Average Time : 2422
```

Input sizes are ,in turn,20,40,100,200,400,800,1600,3200,4000,7000 and 10000.
As seen above ,input size is getting increase ,avarage run time of heap sort increases with respect to n*logn complexity.But since orderless of arrays is not same level , run time of array that has bigger input size maybe smaller than one that has smaller input size.(like input size 3200 and 4000).

3.5.2 Wort-case Performance Analysis

```
Sort type : HeapSort
Run time(Micro seconds) of 1.array : 27 , of 2.array : 491 , of 3.array : 843 , of 4.array :1713 , of  5.array : 3970
```

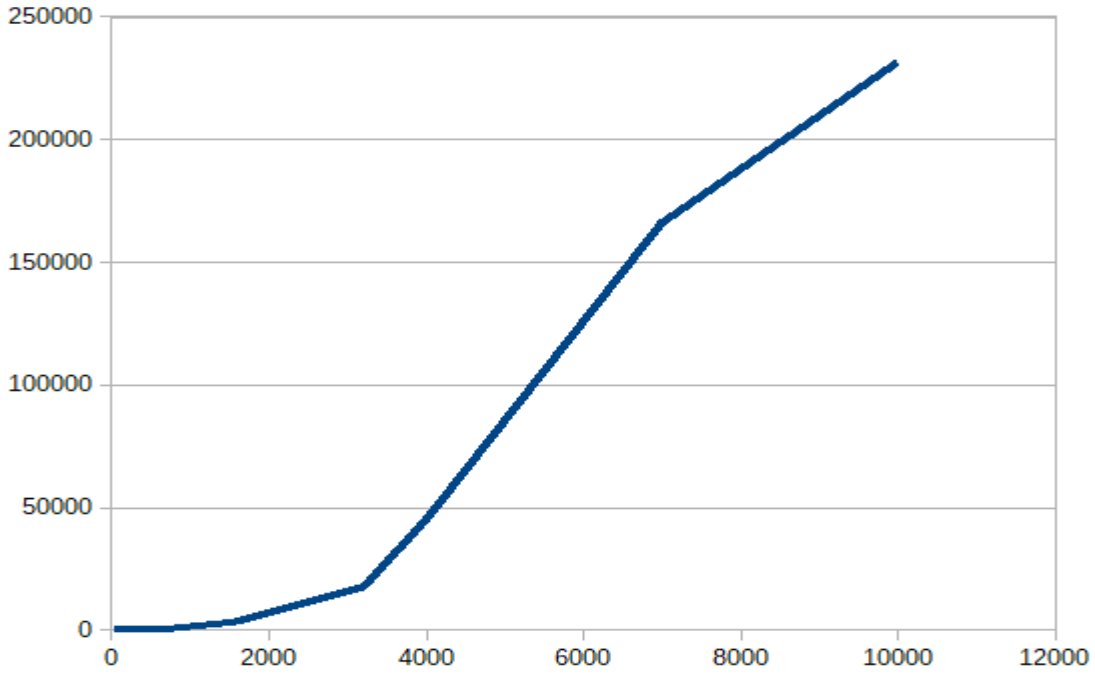
Input sizes are ,in turn,100,1000,2000,5000 and 10000
Time complexity of this heap sort algorithm at worst case is O(n*logn).

4 Average Run Time Analysis Tables And Graph

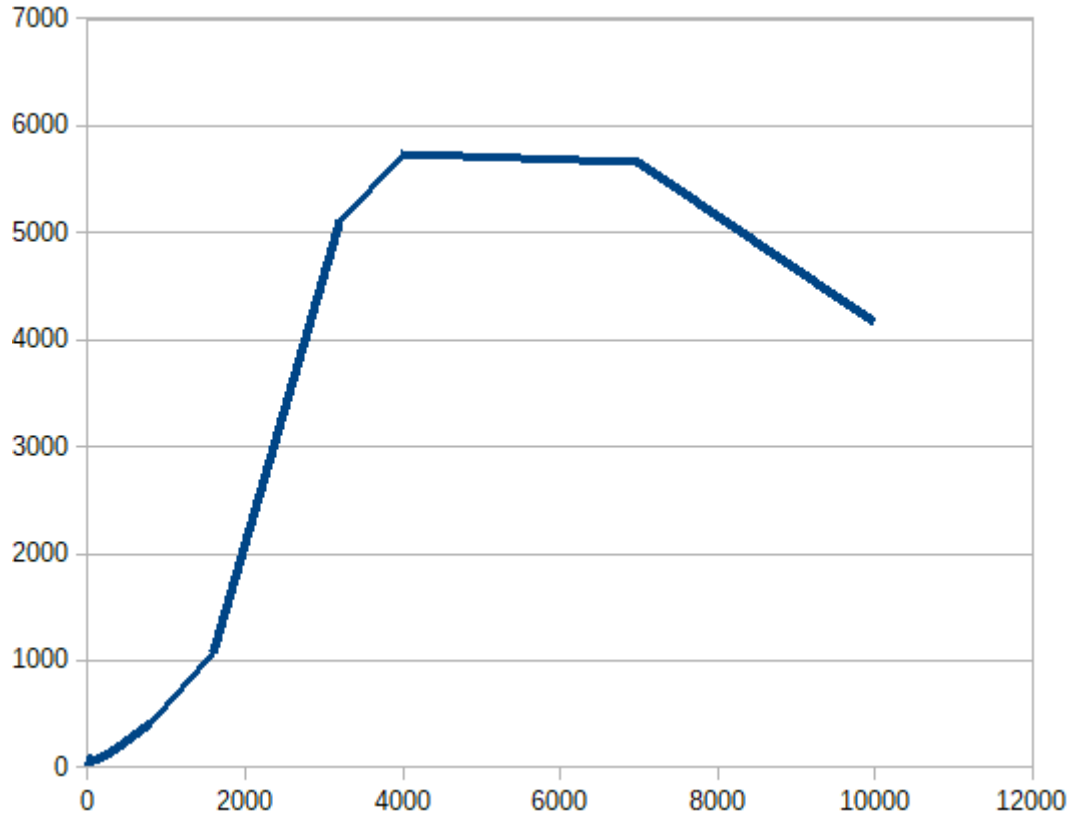
MyMergeSort		MergeSort		QuickSort		HeapSort		InsertionSort	
Time	Size	Time	Size	Time	Size	Time	Size	Time	Size
37	10	12	10	7	10	7	10	2	10
86	20	27	20	20	20	21	20	8	20
164	40	76	40	61	40	52	40	30	40
447	100	67	100	154	100	115	100	50	100
792	200	102	200	120	200	463	200	198	200
3516	400	189	400	109	400	555	400	1873	400
17537	800	425	800	243	800	458	800	481	800
45738	1600	1069	1600	605	1600	1072	1600	1806	1600
166093	3200	5108	3200	3401	3200	1385	3200	7234	3200
231509	4000	5743	4000	721	4000	887	4000	12406	4000
818855	7000	5665	7000	1623	7000	1585	7000	41459	7000
1706434	10000	4160	10000	3301	10000	2442	10000	86941	10000

Run times with respect to input sizes in terms of micro seconds.

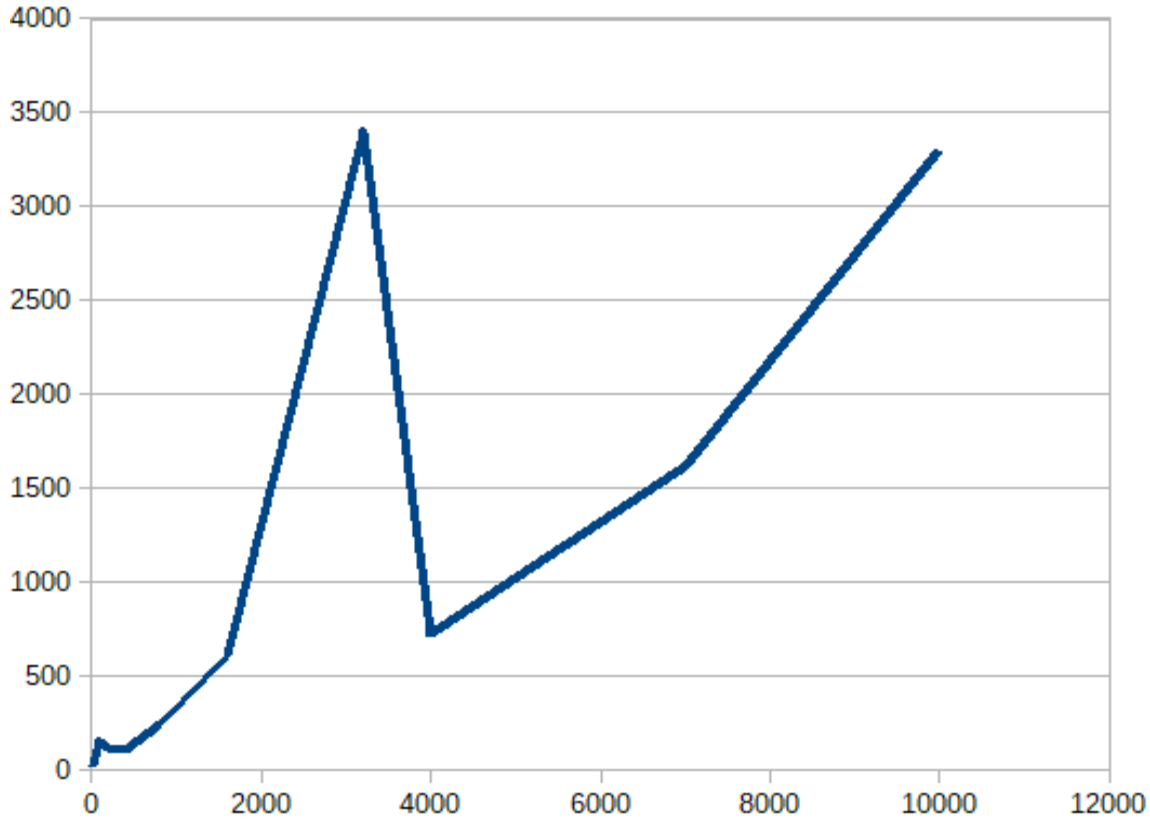
a) MyMergeSort Run Time versus Input Size



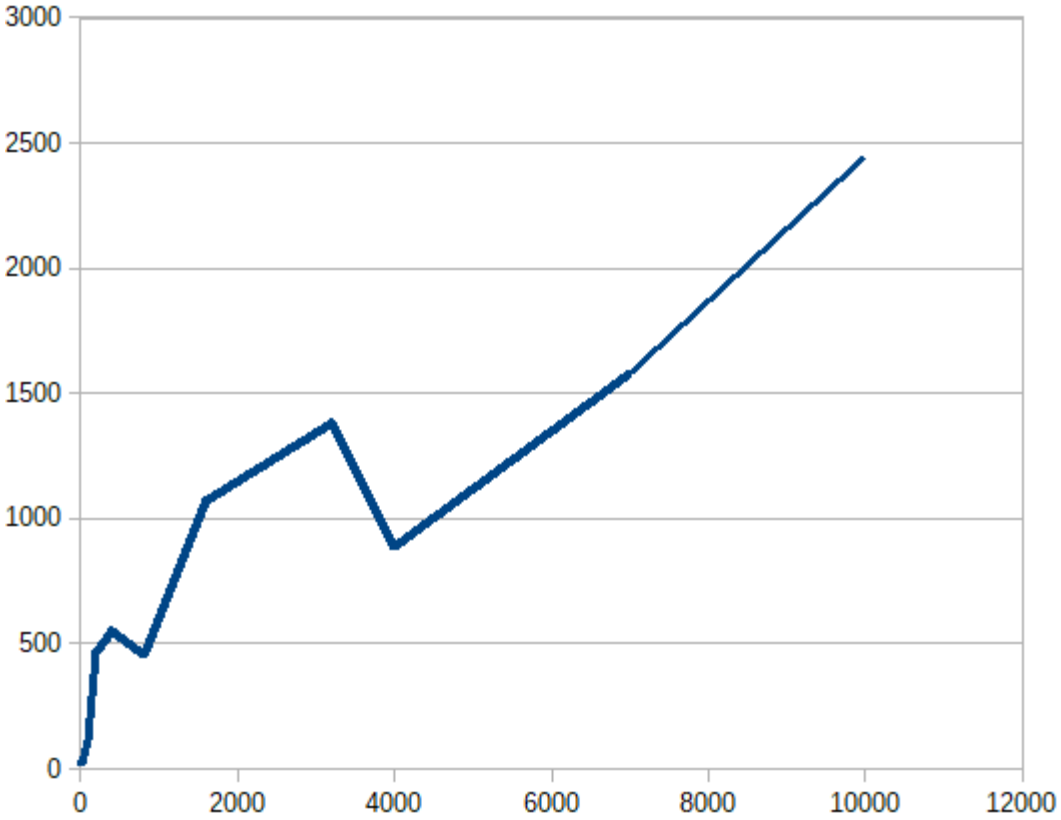
b) MergeSort Run Time versus Input Size



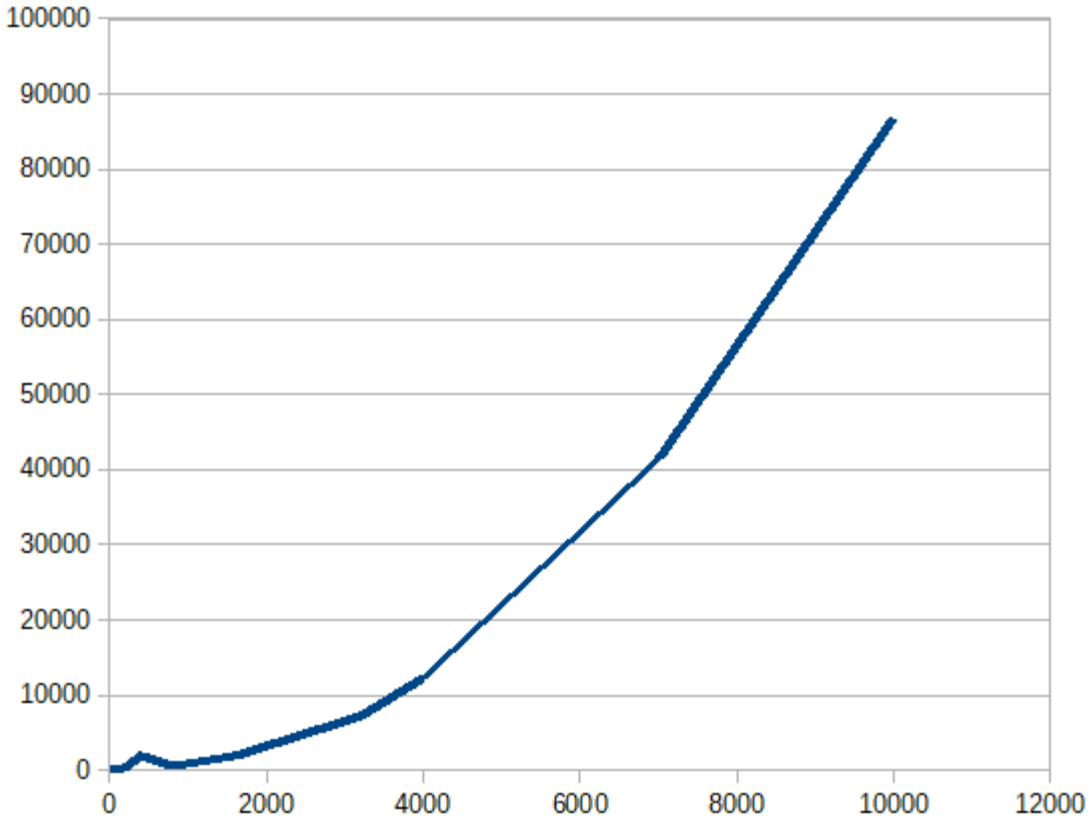
c) QuicSort Run Time versus Input Size



d) HeapSort Run Time versus Input Size

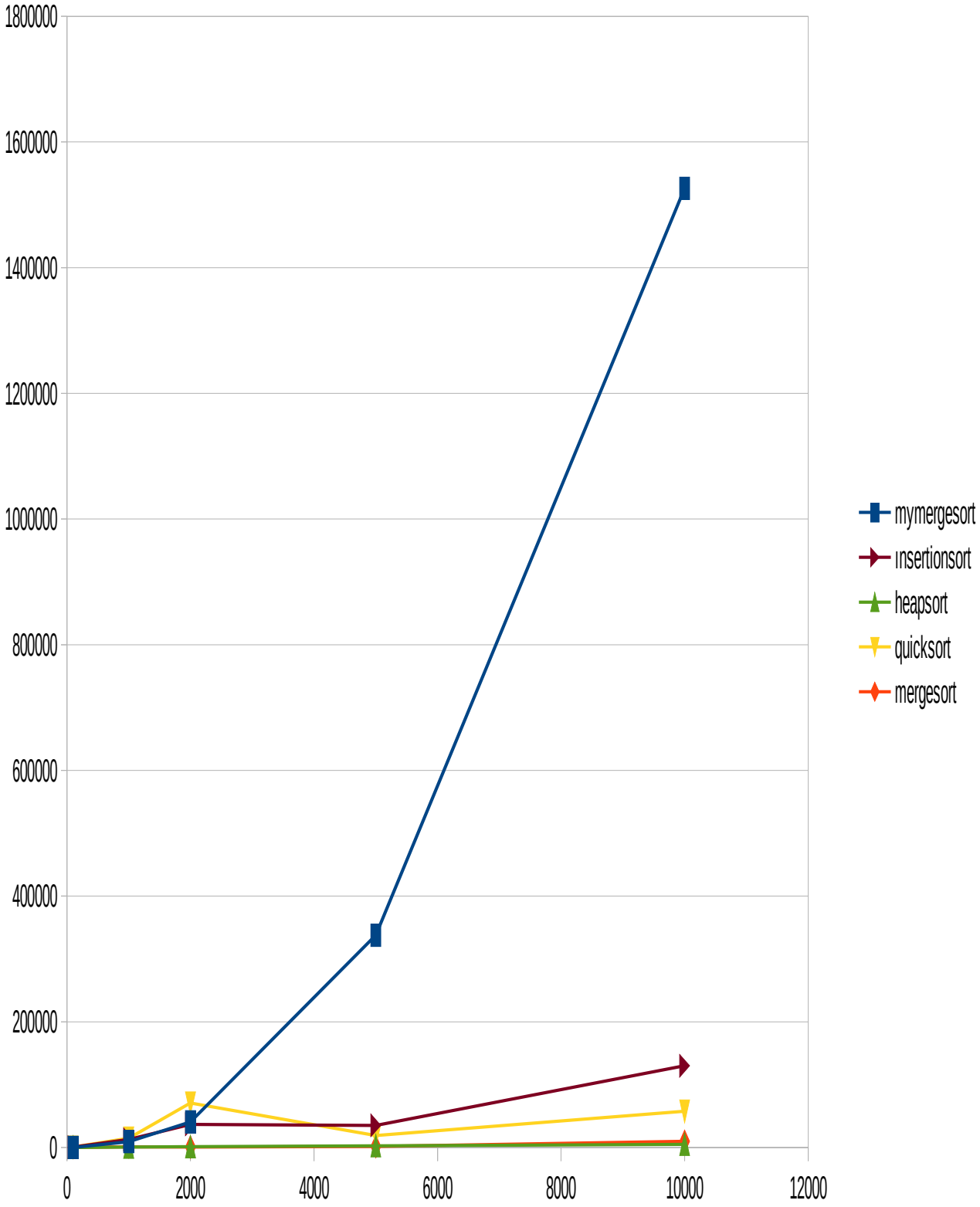


e) InsertionSort Run Time versus Input Size



5 Worst Case Run Time Analysis Tables And Graph

MyMergeSort		MergeSort		QuickSort		HeapSort		InsertionSort	
Time	Size	Time	Size	Time	Size	Time	Size	Time	Size
80	100	144	100	435	100	27	100	559	100
9220	1000	947	1000	14737	1000	692	1000	12779	1000
40686	2000	597	2000	70748	2000	1179	2000	36783	2000
337664	5000	1584	5000	19081	5000	2669	5000	35220	5000
1526241	10000	9721	10000	57612	10000	4871	10000	129937	10000


1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
0
2000
4000
6000
8000
10000
12000
mymergesort
insertionsort
heapsort
quicksort
mergesort