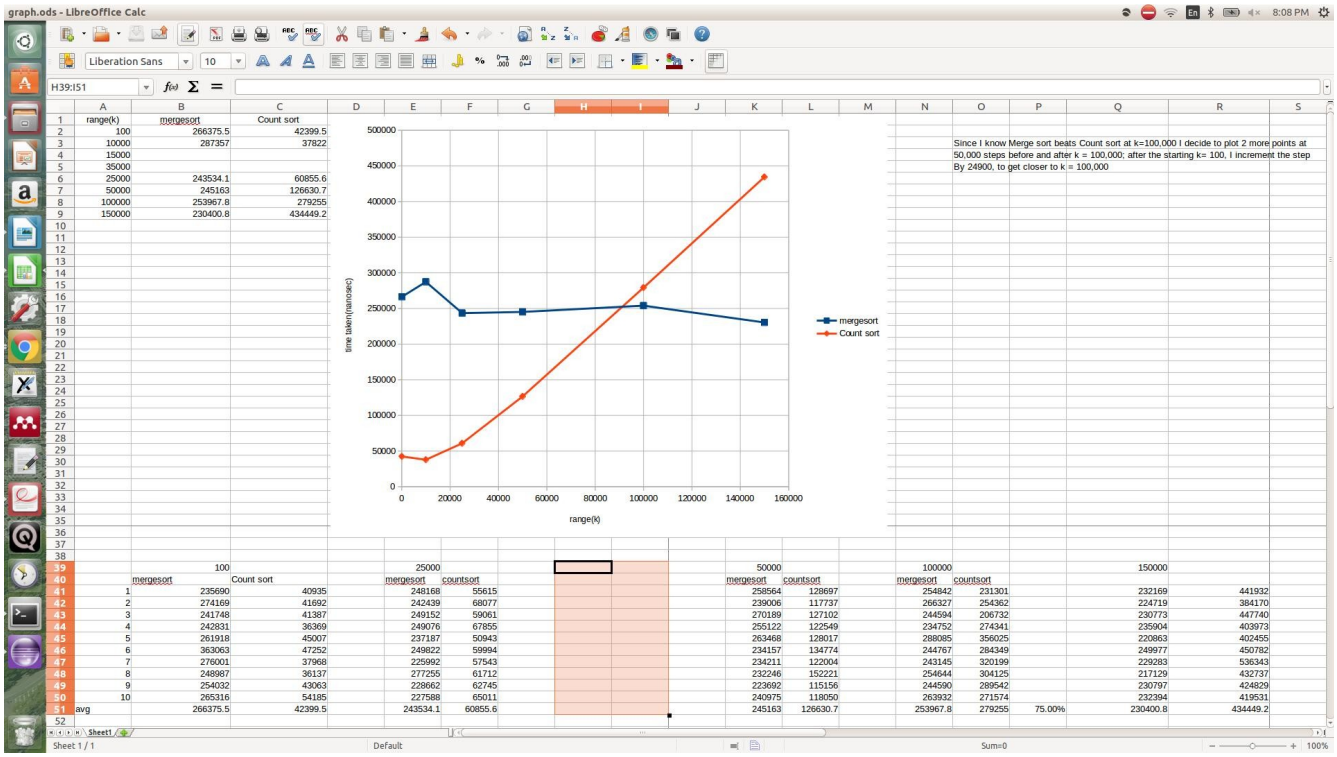
I implemented both Merge Sort and Counting Sort from the website geeksforgeeks.org. According to the graph, Merge Sort beats Counting Sort around k = 90,000.

Since I know Merge sort beats Count sort at k=100,000 I decide to plot 2 more points at 50,000 steps before and after k = 100,000; after the starting k= 100, I increment the step by 24,900 to get closer to k = 100,000.




```
package hw5;
import java.util.*;

public class Sorting {

	public boolean checkFor02k(int arr[], int numSize){
		boolean zero = false;
		boolean k = false;

		for (int i=0; i<arr.length; i++){
			if (arr[i] == 0){
				zero = true;
			}

			if (arr[i] == numSize){
				k = true;
			}
		}

		return (zero && k);
	}
```

```
      protected class MergeSort {
               public void merge(int numbers [], int i, int j, int k) {
                  int mergedSize = k - i + 1;       // Size of merged partition
                  int mergedNumbers [] = new int[mergedSize]; // Temporary array
for merged numbers
                  int mergePos = 0;                 // Position to insert merged
number
                  int leftPos = 0;                  // Position of elements in
left partition
                  int rightPos = 0;                 // Position of elements in
right partition

                  leftPos = i;                      // Initialize left partition
position
                  rightPos = j + 1;                 // Initialize right partition
position

                  // Add smallest element from left or right partition to merged
numbers
                  while (leftPos <= j && rightPos <= k) {
                     if (numbers[leftPos] < numbers[rightPos]) {
                        mergedNumbers[mergePos] = numbers[leftPos];
                        ++leftPos;
                     }
                     else {
                        mergedNumbers[mergePos] = numbers[rightPos];
                        ++rightPos;
                     }
                     ++mergePos;
                  }

                  // If left partition is not empty, add remaining elements to
merged numbers
                  while (leftPos <= j) {
                     mergedNumbers[mergePos] = numbers[leftPos];
                     ++leftPos;
                     ++mergePos;
                  }

                  // If right partition is not empty, add remaining elements to
merged numbers
                  while (rightPos <= k) {
                     mergedNumbers[mergePos] = numbers[rightPos];
                     ++rightPos;
                     ++mergePos;
                  }

                  // Copy merge number back to numbers
                  for (mergePos = 0; mergePos < mergedSize; ++mergePos) {
                     numbers[i + mergePos] = mergedNumbers[mergePos];
                  }
               }

               public void mergeSort(int numbers [], int i, int k) {
                  int j = 0;

                  if (i < k) {
                     j = (i + k) / 2;  // Find the midpoint in the partition
```

```
                // Recursively sort left and right partitions
                mergeSort(numbers, i, j);
                mergeSort(numbers, j + 1, k);

                // Merge left and right partition in sorted order
                merge(numbers, i, j, k);
            }
        }

}
// Java implementation of Counting Sort
protected  class CountingSort
{
   void sort(int arr[])
   {
         //NUMBER SIZE
       int n = arr.length;

       // The output character array that will have sorted arr
       int output[] = new int[n];

       // Create a count array to store count of inidividul
       // characters and initialize count array as 0
       int count[] = new int[35001];
       //
       for (int i=0; i<35001; ++i)
           count[i] = 0;

       // store count of each character
       for (int i=0; i<n; ++i){
           ++count[arr[i]];
       }

       // Change count[i] so that count[i] now contains actual
       // position of this character in output array
       for (int i=1; i<=35000; ++i){
           count[i] += count[i-1];
       }

       // Build the output character array
       for (int i = 0; i<n; ++i)
       {
           output[count[arr[i]]-1] = arr[i];
           --count[arr[i]];
       }

       // Copy the output array to arr, so that arr now
       // contains sorted characters
       for (int i = 0; i<n; ++i){
           arr[i] = output[i];

       }
   }
}

public static void main(String [] args) {
```

```
  final int SIZEOFTIMEARRAY = 100;

  // create array to store total of 100 runs
  long time4Merge[] = new long[SIZEOFTIMEARRAY];
  long time4Count[] = new long[SIZEOFTIMEARRAY];

  int k = 35000;

  //create vars to store average of the 2 sorts
  long avg4Merge = 0;
  long avg4Count = 0;

  Random ranGen = new Random();

  //initialize sorting object
Sorting toInitializeMergeS = new Sorting();

MergeSort MergeS = toInitializeMergeS.new MergeSort();
CountingSort CountS = toInitializeMergeS.new CountingSort();

  final int NUMBERS_SIZE = 2000;

int numbers [] = new int[NUMBERS_SIZE];
int numbers1 [] = new int[NUMBERS_SIZE];

// FOR 0 TO 1000 RUNS, MAKE NEW INPUTS, GET TIME AND STORE TIME IN
ARRAY
int i = 0;

for (int j=0; j<SIZEOFTIMEARRAY; j++){


  for (i=0; i < NUMBERS_SIZE; i++){

        numbers[i] = ranGen.nextInt(k+1);

  }


  for (i=0; i < NUMBERS_SIZE; i++){

        numbers1[i] = ranGen.nextInt(k+1);

  }


  // check to make sure there is 0 and k int in array
  while (!toInitializeMergeS.checkFor02k(numbers, k)){

        for (i=0; i < NUMBERS_SIZE; i++){

              numbers[i] = ranGen.nextInt(k+1);

        }

  }

    // check to make sure there is 0 and k int in array
```

```
  while (!toInitializeMergeS.checkFor02k(numbers1, k)){
        for (i=0; i < NUMBERS_SIZE; i++){
              numbers1[i] = ranGen.nextInt(k+1);
        }
  }
  System.out.println();
  System.out.println(j + " UNSORTED: ");
  for (i = 0; i < NUMBERS_SIZE; ++i) {
        System.out.print(numbers[i] + " ");
  }
  System.out.println();

  for (i = 0; i < NUMBERS_SIZE; ++i) {
        System.out.print(numbers1[i] + " ");
  }

  System.out.println();
  System.out.println();

  /* initial call to mergesort with index */
  //stop and record timer for merge in array
    long startTime = System.nanoTime();
  MergeS.mergeSort(numbers, 0, NUMBERS_SIZE - 1);
  long stopTime = System.nanoTime();

  time4Merge[j] = stopTime - startTime;

//  System.out.println("time for merge " + j + ": " + time4Merge[j]);



  //start timer for count
    startTime = System.nanoTime();
  //call to counting sort w index
        CountS.sort(numbers1);
  //stop and record timer for count in array
  stopTime = System.nanoTime();

  time4Count[j] = stopTime - startTime;
/*
  System.out.println("time for count " + j + ": " + time4Count[j]);
```

```
              System.out.println( j+" SORTED: ");

              for (i = 0; i < NUMBERS_SIZE; ++i) {

                    System.out.print(numbers[i] + " ");

              }


                System.out.println();

              for (i = 0; i < NUMBERS_SIZE; ++i) {

                    System.out.print(numbers1[i] + " ");

              }

              System.out.println();
              */
            }

            // average the times and print the avg of 100 runs



            for (int j=0; j<SIZEOFTIMEARRAY; j++){
              avg4Merge += time4Merge[j];
              avg4Count += time4Count[j];
            }

            avg4Merge /= SIZEOFTIMEARRAY;
            avg4Count /= SIZEOFTIMEARRAY;

            System.out.println("average time of 100000 runs for Merge is: " +
avg4Merge);
            System.out.println("average time of 100000 runs for Count is: " +
avg4Count);

            return;
      }

}
```