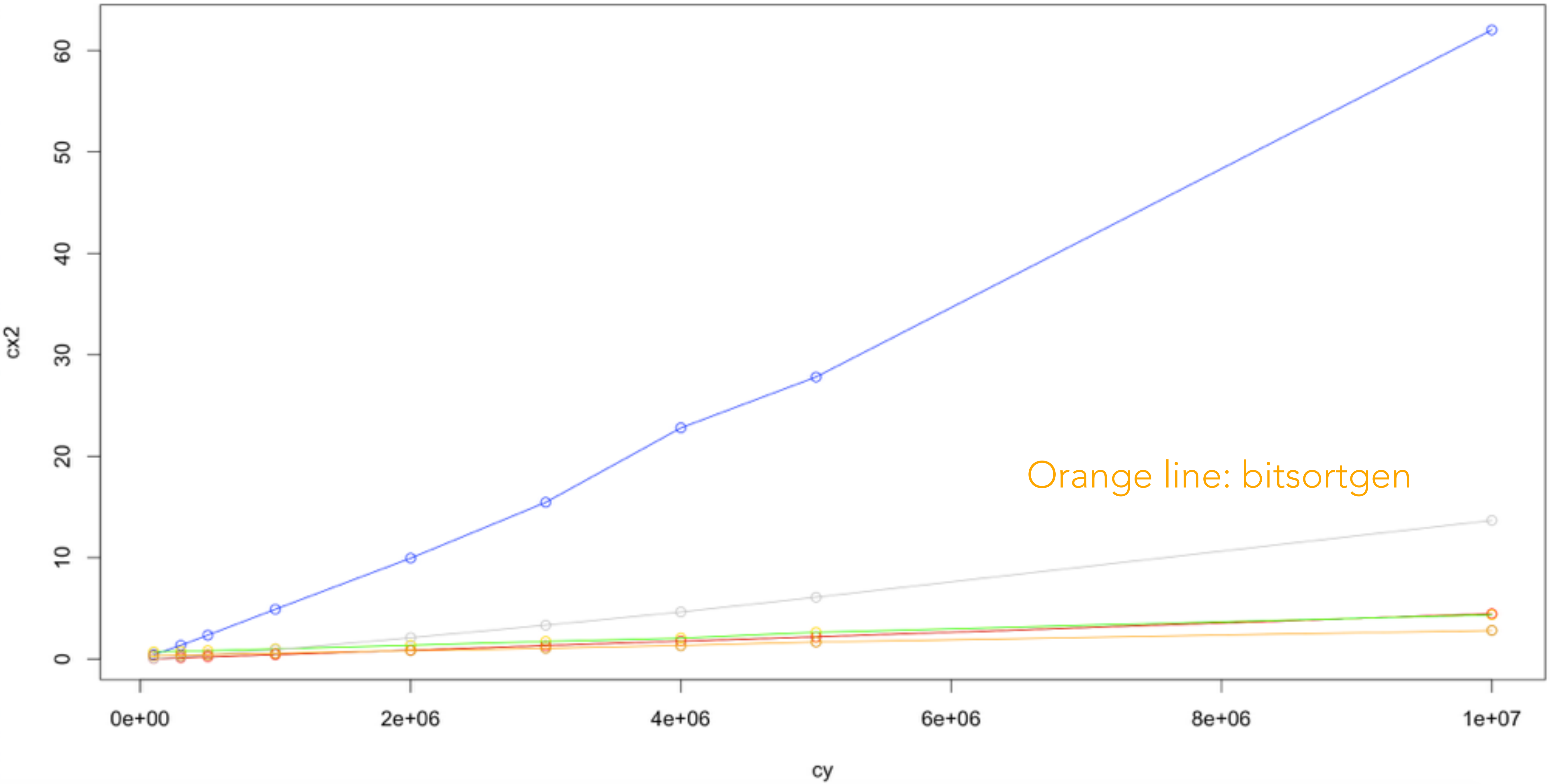
BY ERICA TU LUAN FEBRUARY 11, 2016

SORTING LARGE DATA FILES

THE RESULT

Dataset Size	Bitsortgen	Sort(A)	Sort(B)	Sort(C)	Bitsort
100K	0.328	0.060000	0.04000	0.4309091	0.6990909
300K	0.388	0.2281818	0.1253846	1.352727	0.7627273
500K	0.445	0.4081818	0.2075000	2.355455	0.8227273
1M	0.558	0.9136364	0.4254545	4.904545	1.003636
2M	0.828	2.099091	0.8690909	9.940909	1.350000
3M	1.058	3.334545	1.324545	15.44273	1.734545
4M	1.328	4.639091	1.768182	22.78818	2.057273
5M	1.673	6.089091	2.185455	27.80545	2.630909
10M	2.816	13.66455	4.468182	62.02818	4.366364


Blue line: Sort (c)
Red line: Sort (b)
Grey line: Sort (a)
Green line: Bitsort
cx2
cy
0
10
20
30
40
50
60
0e+00
2e+06
4e+06
6e+06
8e+06
1e+07



cx2
0
10
20
30
40
50
60
0e+00
2e+06
4e+06
6e+06
8e+06
1e+07
cy
Orange line: bitsortgen

MY DATA ACCURACY

- Each data in the form for the sorts part is calculated by the mean of 11 times of repeat experiments.
- Each data in the form for the file generating part is calculated by the mean of 5 times of repeat experiments.
- Every execution is run on the same computer.


BITSORTGEN.C

BITSORTGEN.C

- An equivalent version of Fisher–Yates shuffle/ Knuth shuffle

The algorithm:

```
-- To shuffle an array a of n elements (indices 0..n-1):
for i from 0 to n-2 do
     j ← random integer such that 0 ≤ j < n-i
     exchange a[i] and a[i+j]
```

Via Wikipedia “Fisher–Yates shuffle"

BITSORTGEN.C

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#define MAXN 100000000    /* Max 100 million numbers */
int x[MAXN];

int randint(int a, int b)
{   /* return a + (RAND_MAX * rand() + rand()) % (b + 1 - a); */
    return a + (rand() % (b - a + 1));
}
```

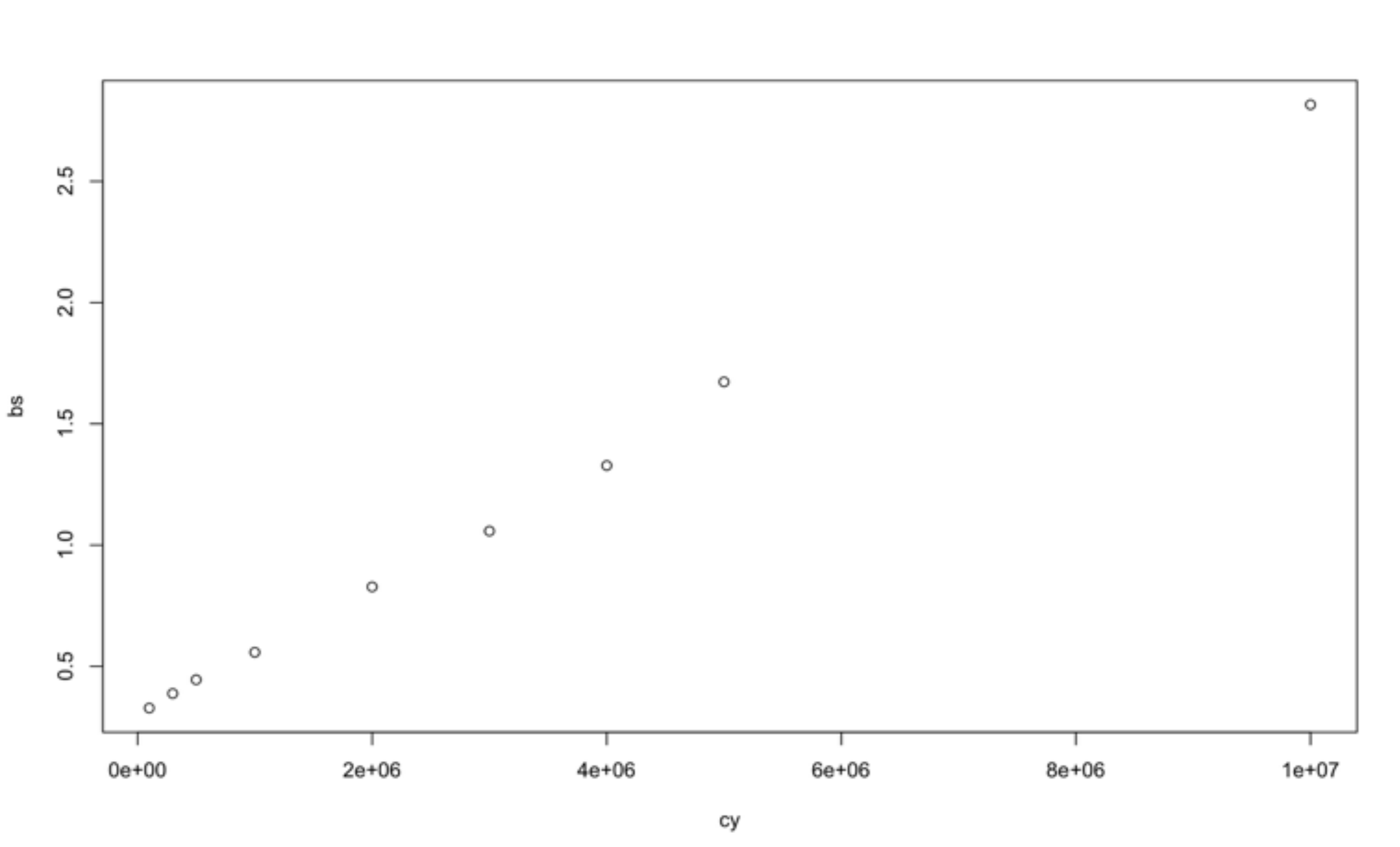
```c
int main(int argc, char *argv[])
{    int i, k, n, t, p;
     srand((unsigned) time(NULL));
     k = atoi(argv[1]);
     n = atoi(argv[2]);
     for (i = 0; i < n; i++)
         x[i] = i;
     for (i = 0; i < k; i++) {
         p = randint(i, n);
         t = x[p]; x[p] = x[i]; x[i] = t;
         printf("%d\n", x[i]);
     }
     return 0;
}
```

O(n) for looping from 0 to n-1

O(k) for looping from 0 to k-1

```
int main(int argc, char *argv[])
{   int i, k, n, t, p;
    srand((unsigned) time(NULL));
    k = atoi(argv[1]);
    n = atoi(argv[2]);
    for (i = 0; i < n; i++)
        x[i] = i;
    for (i = 0; i < k; i++) {
        p = randint(i, n);
        t = x[p]; x[p] = x[i]; x[i] = t;
        printf("%d\n", x[i]);
    }
    return 0;
}
```

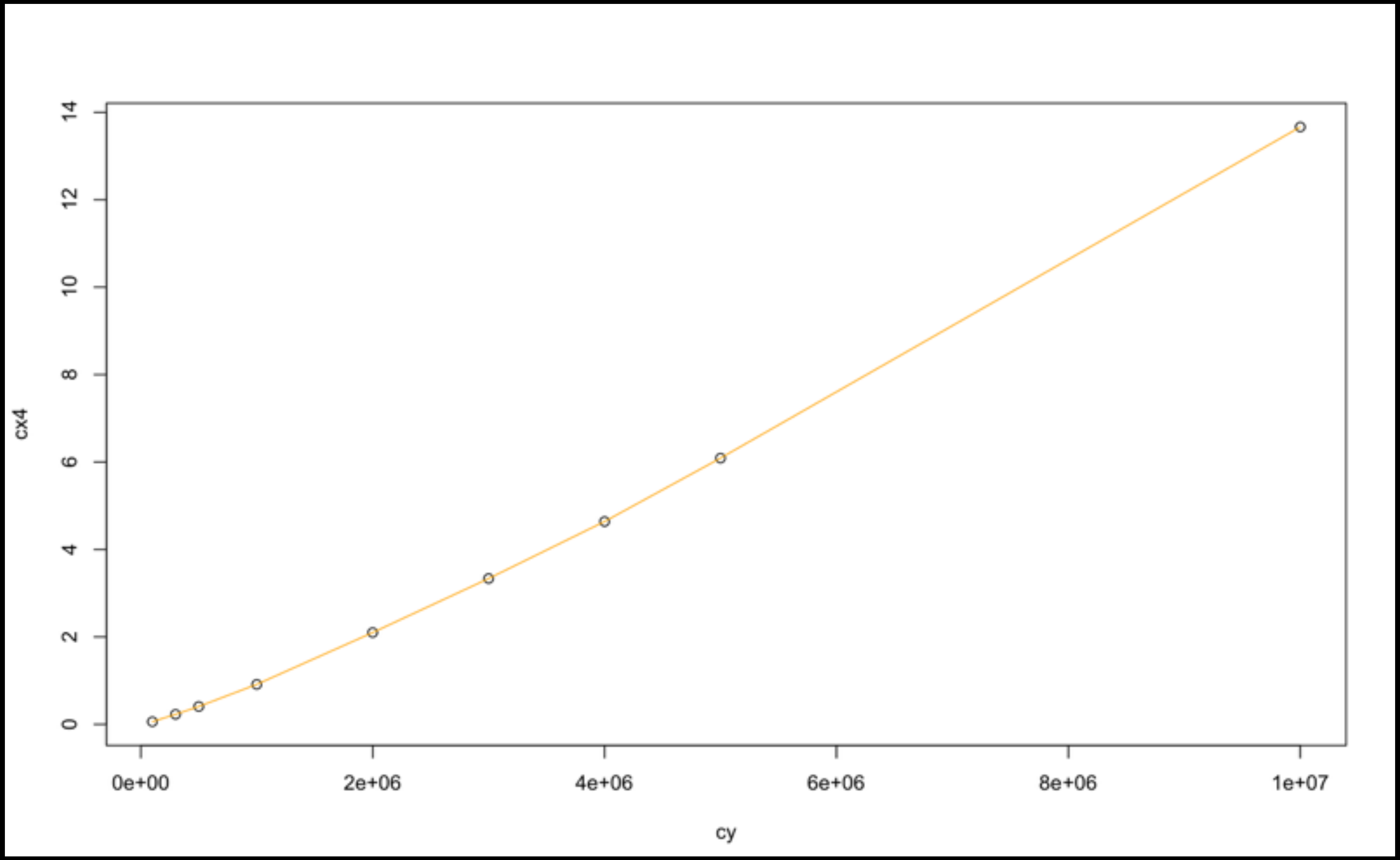
Bitsortgen
0.328
0.388
0.445
0.558
0.828
1.058
1.328
1.673
2.816




SORT(A)

THE LINUX SYSTEM SORT

Sort (A)
0.060000
0.2281818
0.4081818
0.9136364
2.099091
3.334545
4.639091
6.089091
13.66455



THE LINUX SYSTEM SORT ALGORITHM

Sorting algorithm [edit]

The implementation in GNU Core Utilities, used on Linux, employs the merge sort algorithm.

Via Wikipedia "Unix sort"

REGRESSION GUESS

Nonlinear regression model

model: cx4 ~ K * cy * log(cy) + B * cy + C

data: parent.frame()

K	B	C
2.212e-07	-2.205e-06	5.123e-02

residual sum-of-squares: 0.004307

The linear regression model:

Coefficients:

(Intercept)	cy
-4.445e-01	1.368e-06

residual sum-of-squares: 0.8039869


SORT(B)

QSORTINTS.C (QUICK SORT)

```c
#include <stdio.h>
#include <stdlib.h>
/* function to compare two integeres */
int intcomp(int *x, int *y)
{   return *x - *y;
} /* end of intcomp */
int a[100000000];           /* the array to store 100 million integers */
int main()
{   int i, n=0;
    /* read the data into array, a */
    while (scanf("%d", &a[n]) != EOF)
        n++;
 /* sort a using quick sort library function
    qsort(a, n, sizeof(int), intcomp);
   /* output the data */
    for (i = 0; i < n; i++)
    printf("%d\n", a[i]);
    return 0;
} /* end of main */
```

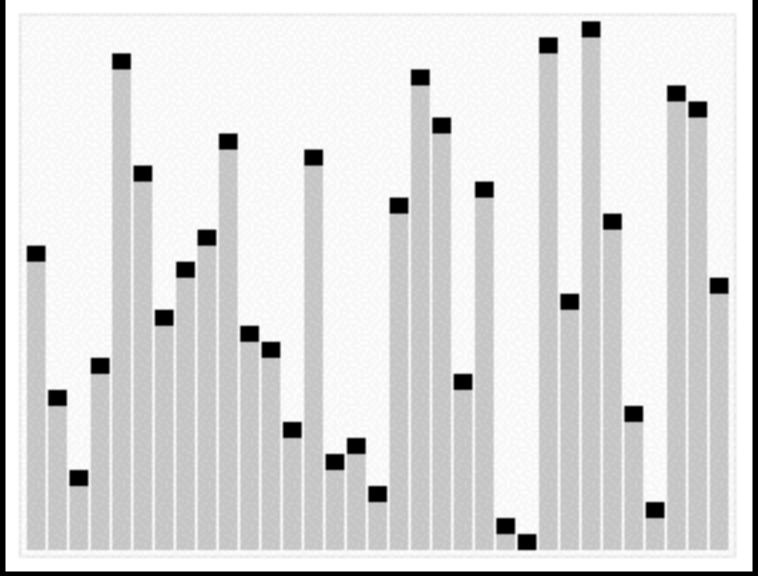
O(n) for looping from 0 to n-1

What is the time complexity for a quick sort?

O(n) for looping from 0 to n-1

ANALYSTS OF ALGORITHM OF QUICK SORT

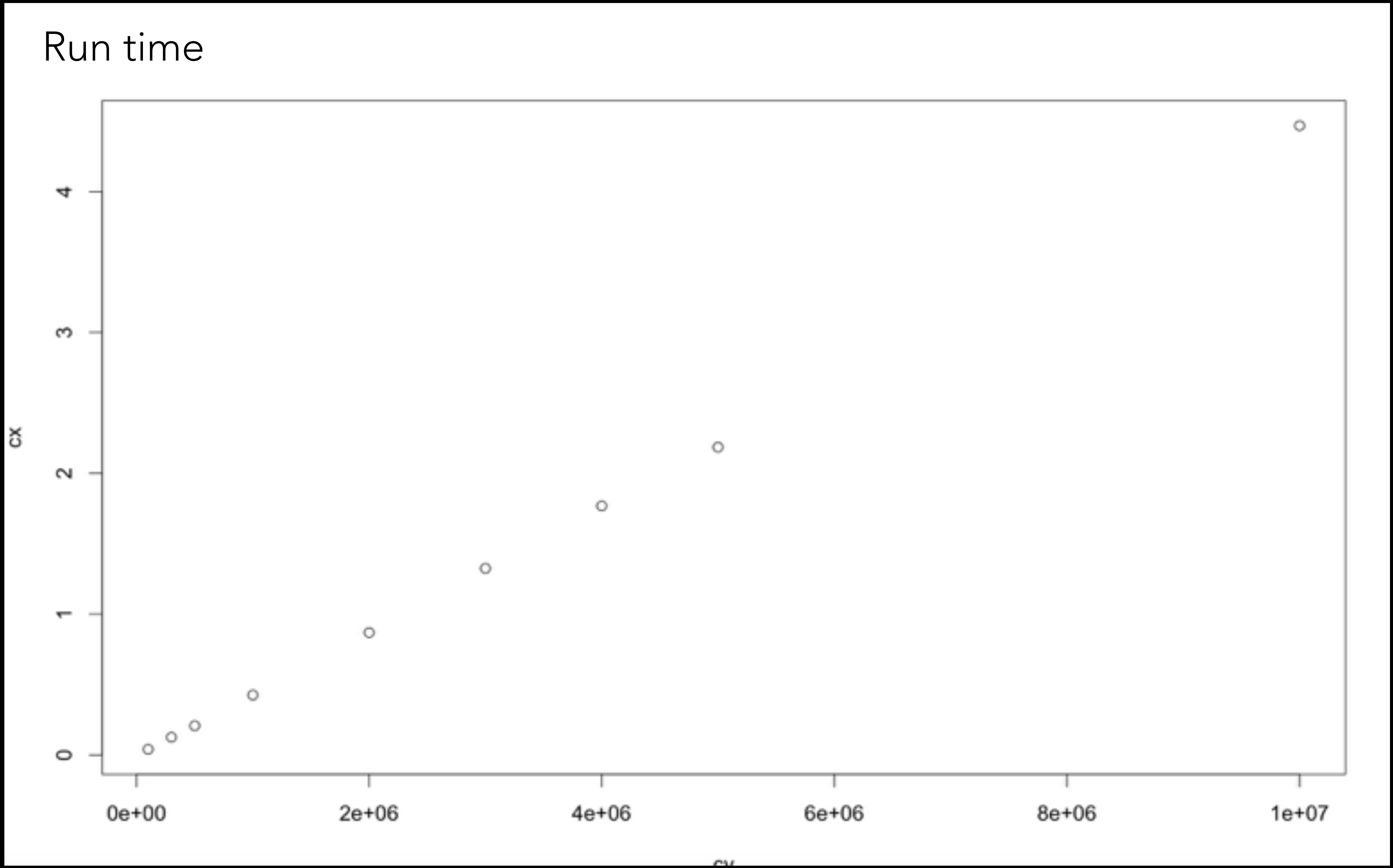
- Best case: O(nlogn)
- Worse case: O(n^2)
- Average case: O(nlogn)



Via Wikipedia

DATA ANALYSIS

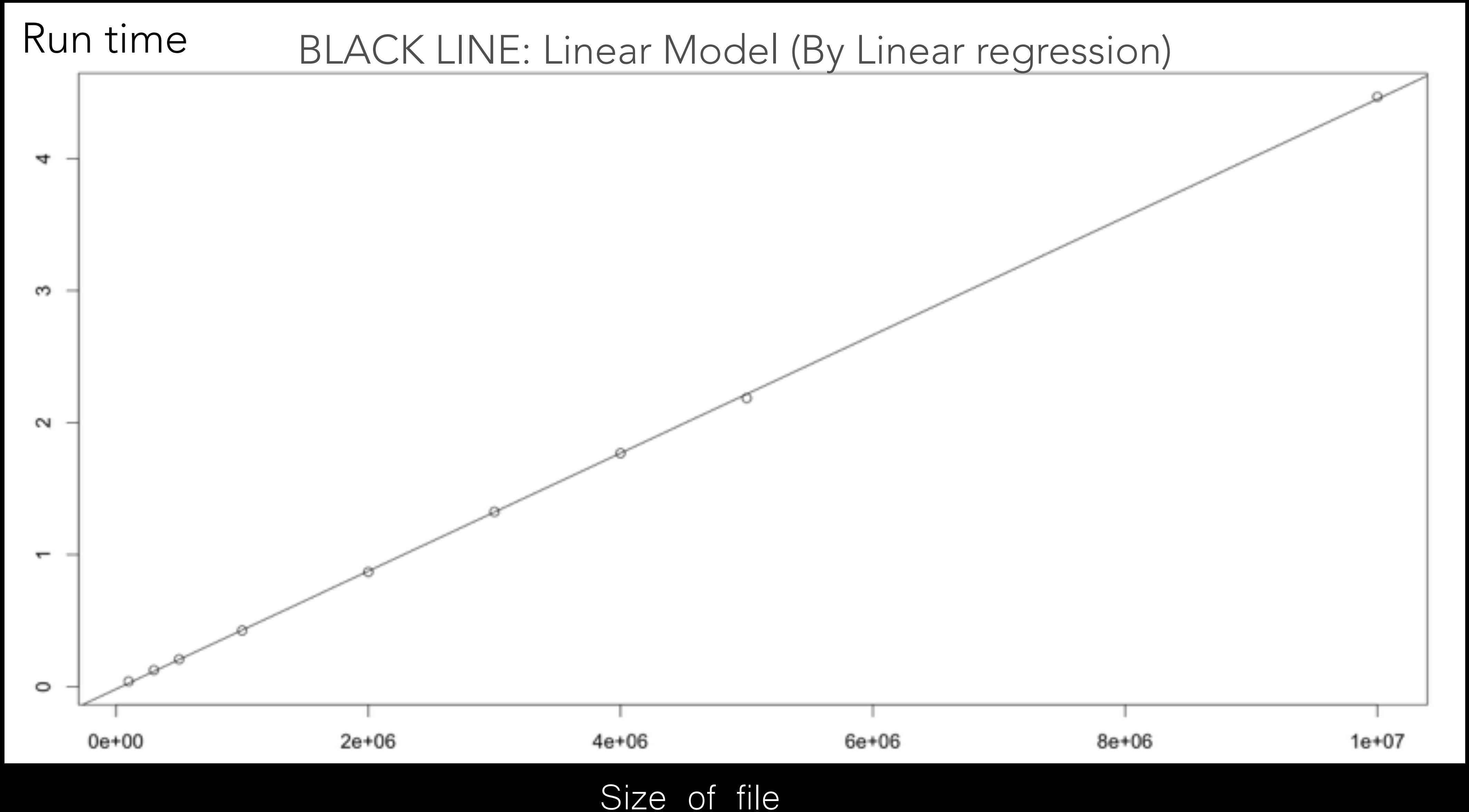
Sort (B)
0.04000
0.1253846
0.2075000
0.4254545
0.8690909
1.324545
1.768182
2.185455
4.468182



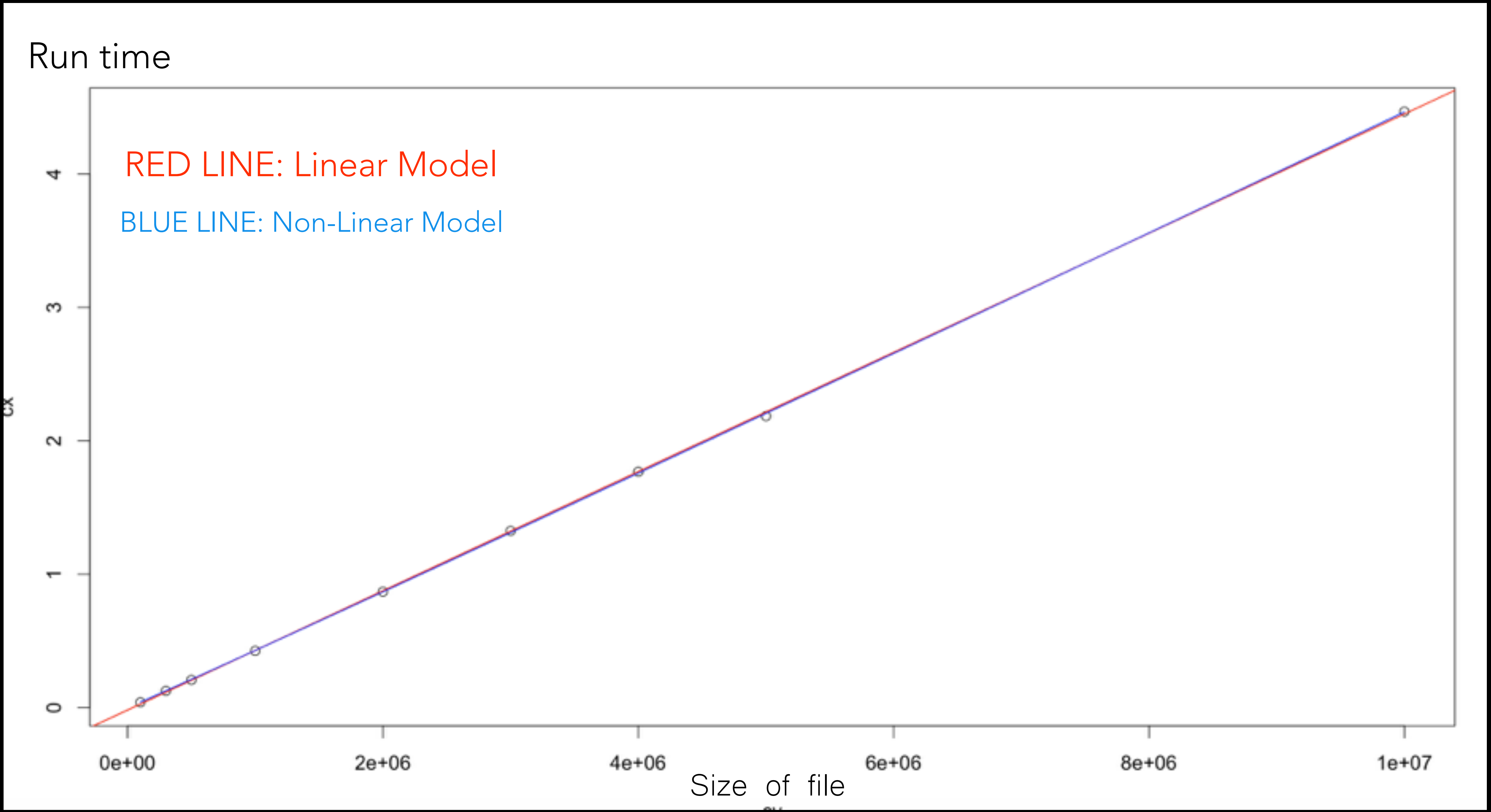
Size of file

Sort (B)
0.04000
0.1253846
0.2075000
0.4254545
0.8690909
1.324545
1.768182
2.185455
4.468182

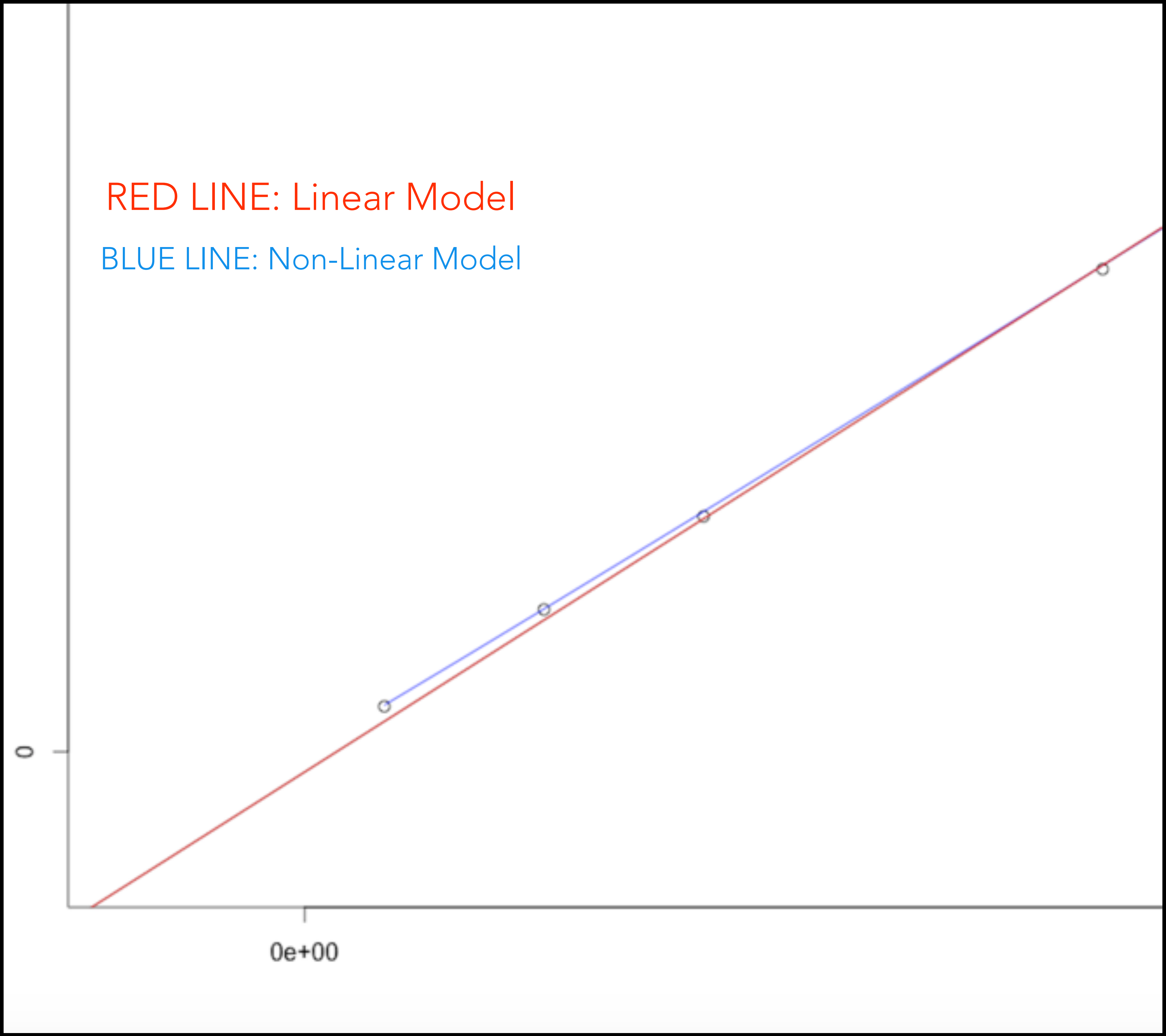
Quite linear, right?



CAN WE GET A BETTER FIT MODEL?



DATA ANALYSIS WITH MODELS
WHEN ZOOM IN



THE FORMULA FOR THE TWO MODELS

BLUE LINE: Non-Linear function : run_time=
7.706e-09*size_of_file*log(size_of_file)+3.223e-07*size_of_file;
(The model: y=k*n*logn+b*n)
Residual sum-of-squares: 0.0007289

RED LINE: Linear function: run_time=4.469e-07 *size_of_file+(-1.794e-02)
(The model: y=kn+b)
Residual sum-of-squares: 0.001589269

GNU SOURCE CODE COMMENTS

Referred to glibc/stdlib/qsort.c:

```
/* Order size using quicksort.  This implementation incorporates
   four optimizations discussed in Sedgewick:

   1. Non-recursive, using an explicit stack of pointer that store the
      next array partition to sort.  To save time, this maximum amount
      of space required to store an array of SIZE_MAX is allocated on the
      stack.  Assuming a 32-bit (64 bit) integer for size_t, this needs
      only 32 * sizeof(stack_node) == 256 bytes (for 64 bit: 1024 bytes).
      Pretty cheap, actually.

   2. Chose the pivot element using a median-of-three decision tree.
      This reduces the probability of selecting a bad pivot value and
      eliminates certain extraneous comparisons.

   3. Only quicksorts TOTAL_ELEMS / MAX_THRESH partitions, leaving
      insertion sort to order the MAX_THRESH items within each partition.
      This is a big win, since insertion sort is faster for small, mostly
      sorted array segments.

   4. The larger of the two sub-partitions is always pushed onto the
      stack first, with the algorithm then concentrating on the
      smaller partition.  This *guarantees* no more than log (total_elems)
      stack size is needed (actually O(1) in this case)!  */
```


SORT(C)

SORTINTS.CPP

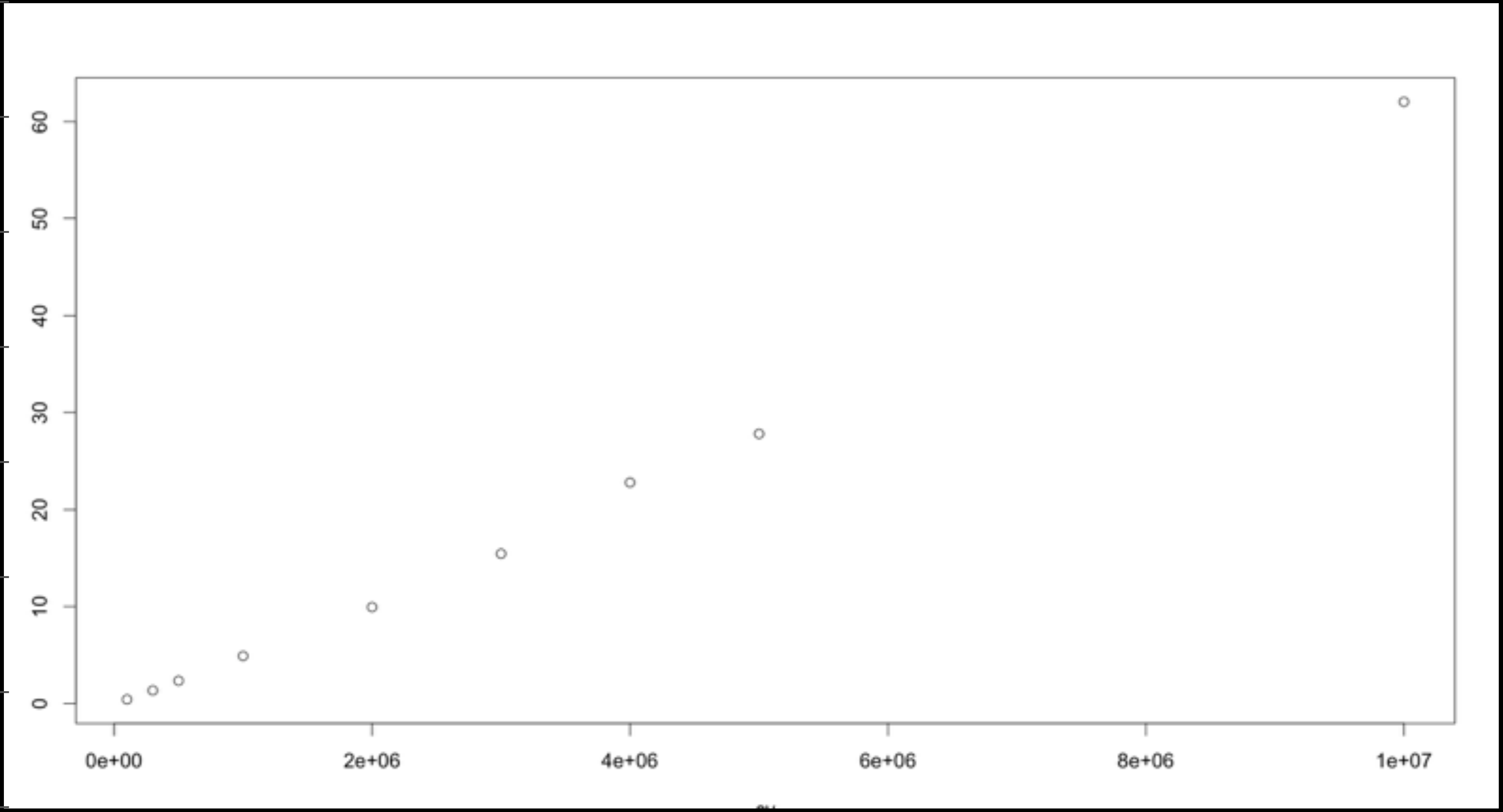
```
#include <iostream>
#include <set>
using namespace std;

int main()
{   set<int> S;
    int i;
    set<int>::iterator j
    while (cin >> i)
        S.insert(i);
    for (j = S.begin(); j != S.end(); ++j)
        cout << *j << "\n";
    return 0;
}
```

What is the time complexity for inserting one element?

O(n) for looping from 0 to n-1

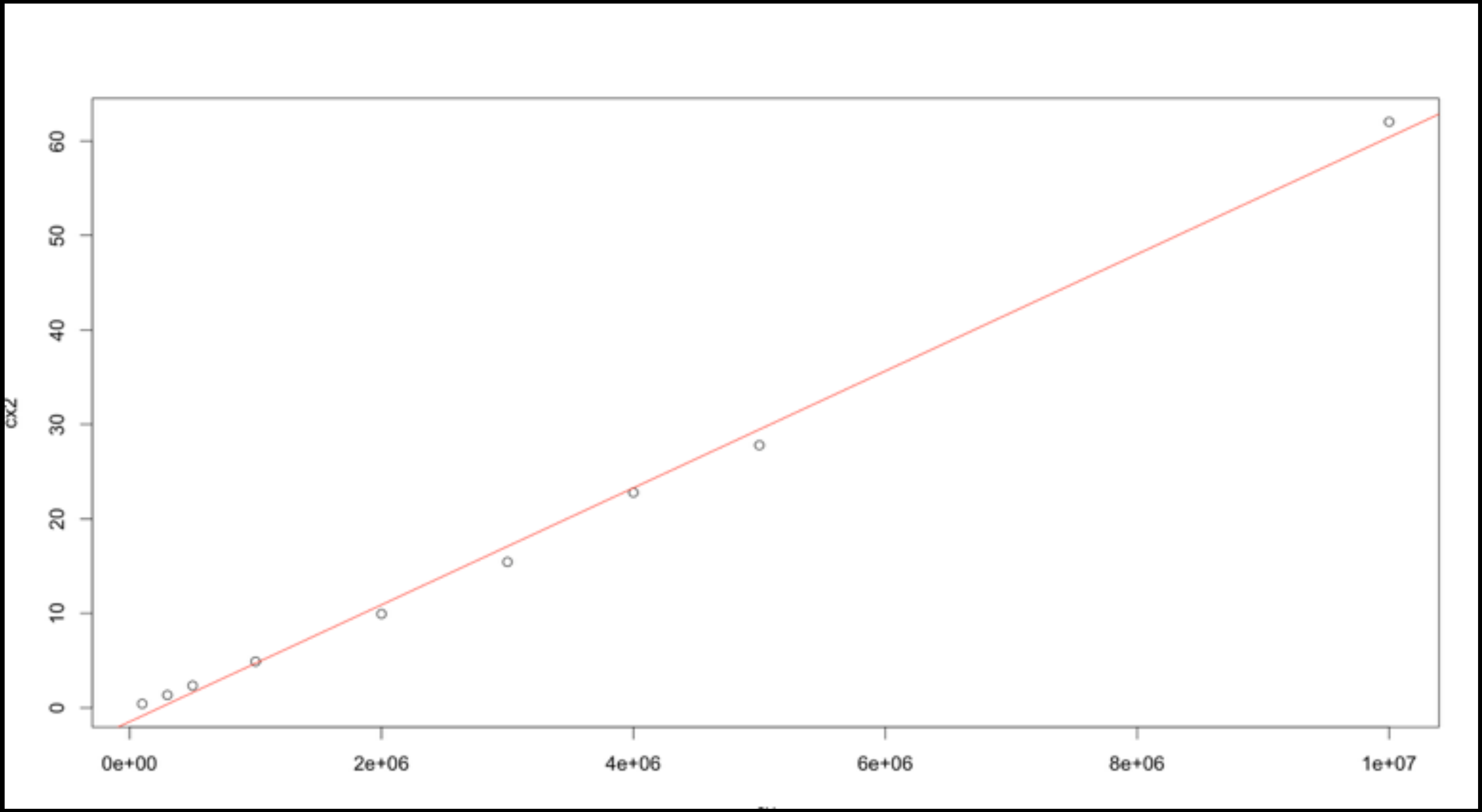
DATA ANALYSIS

Sort (C)
0.4309091
1.352727
2.355455
4.904545
9.940909
15.44273
22.78818
27.80545
62.02818



Sort (C)
0.4309091
1.352727
2.355455
4.904545
9.940909
15.44273
22.78818
27.80545
62.02818

Still quite linear, right?



How does the insert() work?

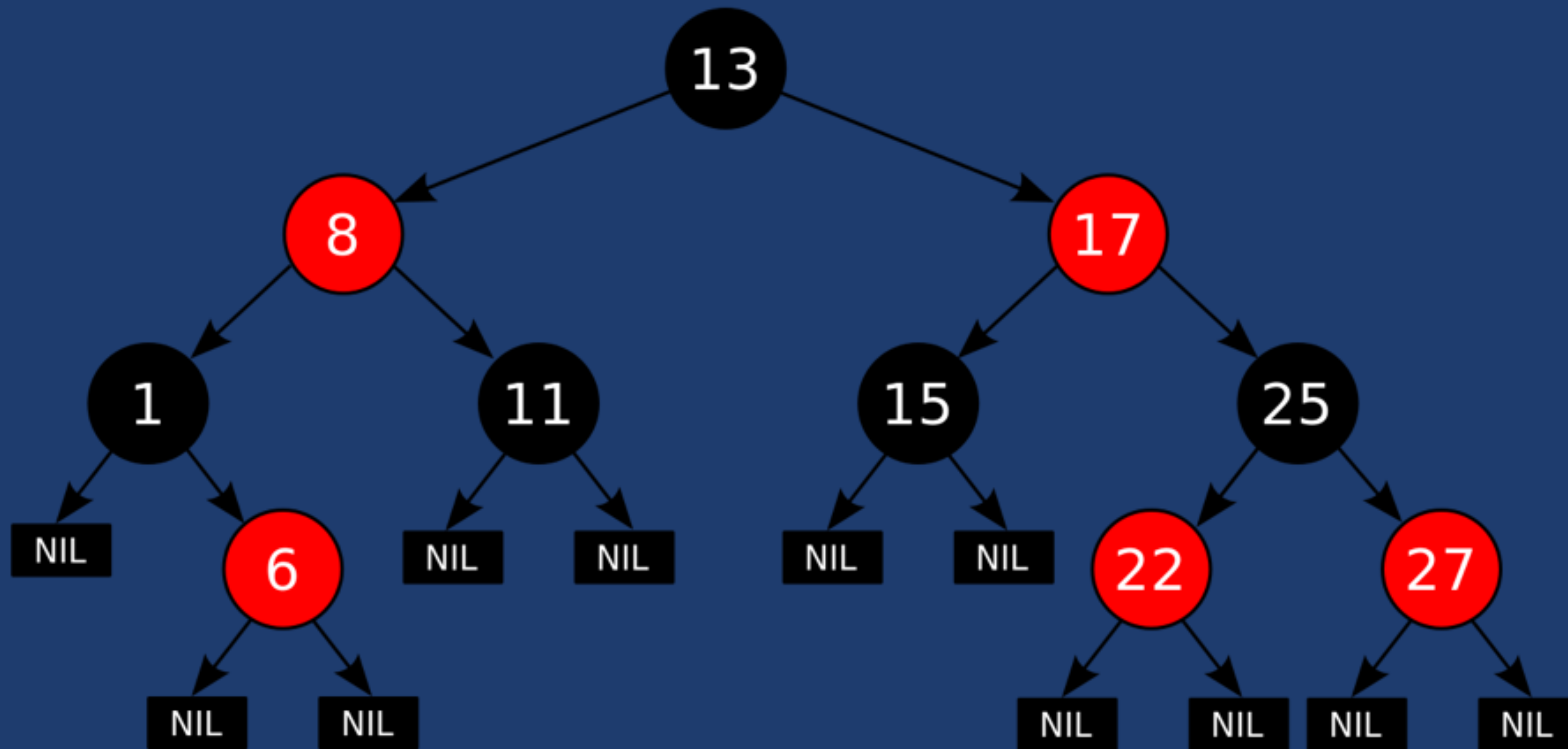
std::set

- std::set is an associative container that contains a sorted set of unique objects of type Key. Sorting is done using the key comparison function Compare. Search, removal, and insertion operations have logarithmic complexity. Sets are usually implemented as red-black trees

-http://en.cppreference.com/w/cpp/container/set

RED-BLACK TREES

Self-balancing binary search tree

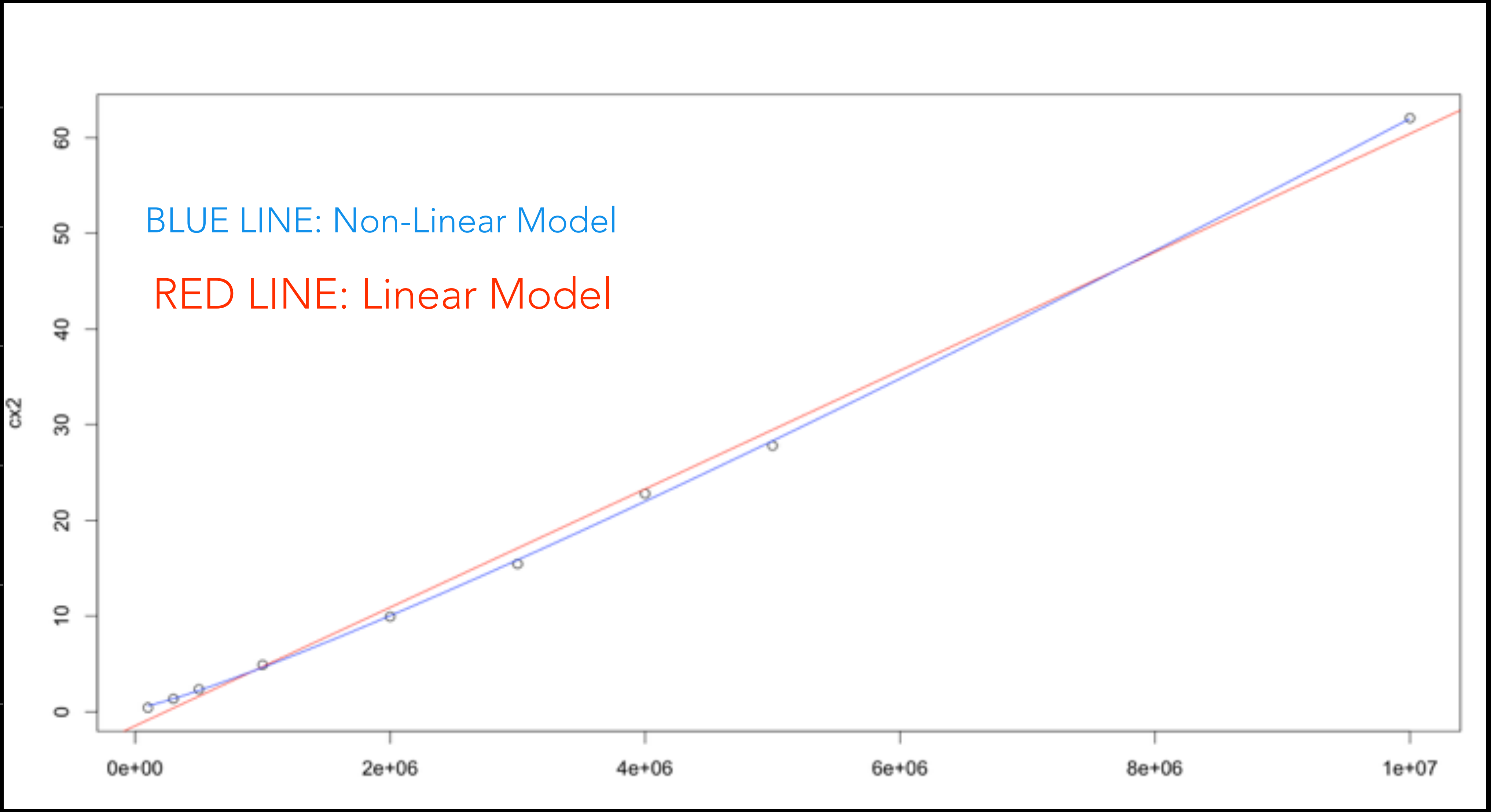


via Wikipedia

RED-BLACK TREES

- Theorem: A red-black tree with n keys has height $h \leq 2 \lg(n + 1)$.
- Red-black trees will never reach the worse case for the binary search tree because of the height guarantee.

Sort(C)
0.4309091
1.352727
2.355455
4.904545
9.940909
15.44273
22.78818
27.80545
62.02818



THE FORMULA FOR THE TWO MODELS

BLUE LINE: Non-Linear function : run_time=
8.287e-07 * file_size * log(file_size) + (-7.198e-06)* file_size + 3.902e-01
(The model: y=k*n*logn+b*n+c)
Residual sum-of-squares: 1.218

RED LINE: Linear function: run_time=6.187e-06 *size_of_file+(-1.467e+00)
(The model: y=kn+b)
Residual sum-of-squares: 12.43855


BIT SORT

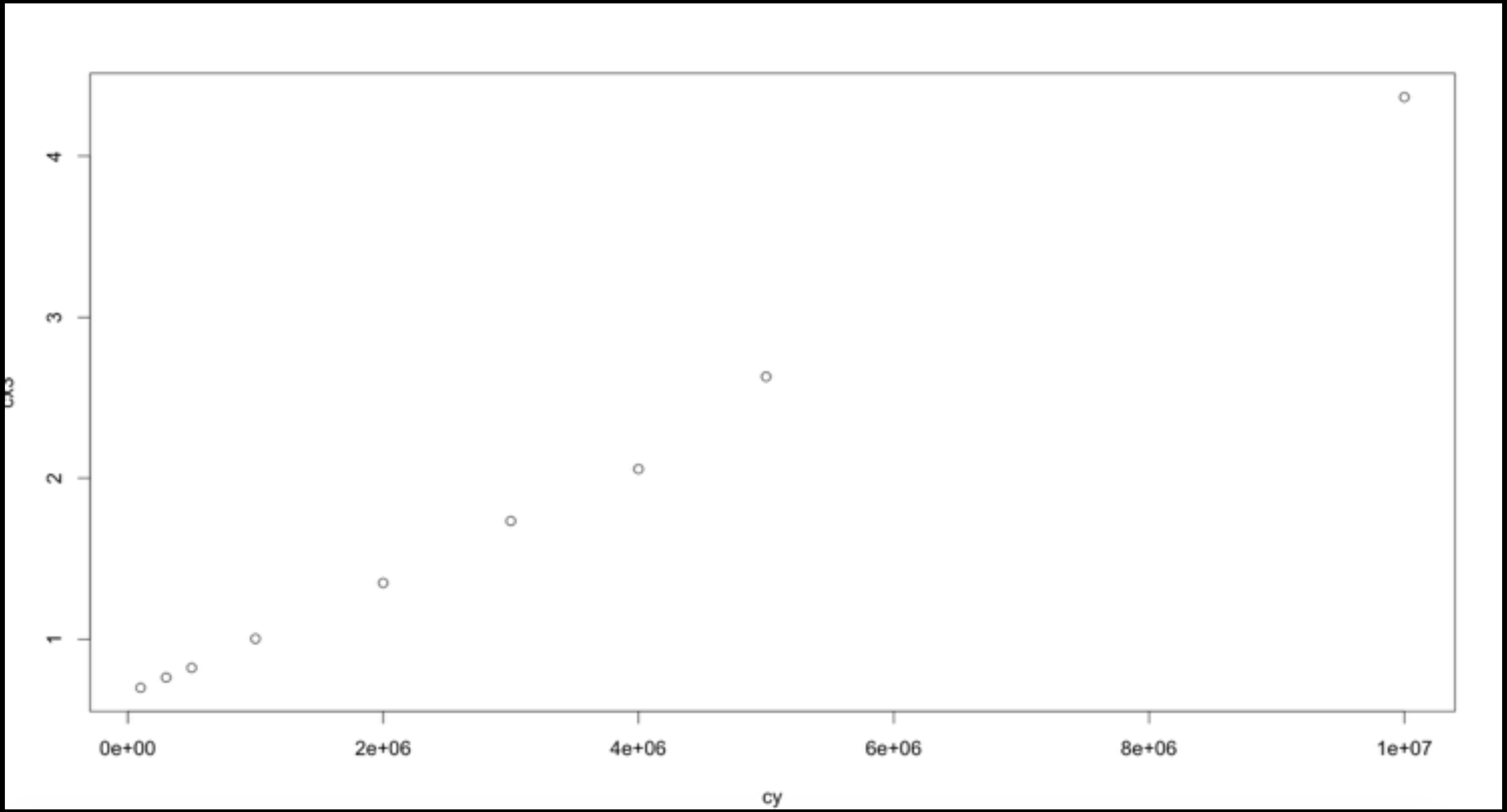
BITSORT.C

```
#include <stdio.h>


#define BITSPERWORD 32

#define SHIFT 5

#define MASK 0x1F

#define N 100000000

int a[1 + N/BITSPERWORD];


void set(int i) {        a[i>>SHIFT] |=  (1<<(i & MASK)); }

void clr(int i) {        a[i>>SHIFT] &= ~(1<<(i & MASK)); }

int  test(int i){ return a[i>>SHIFT] &   (1<<(i & MASK)); }
```

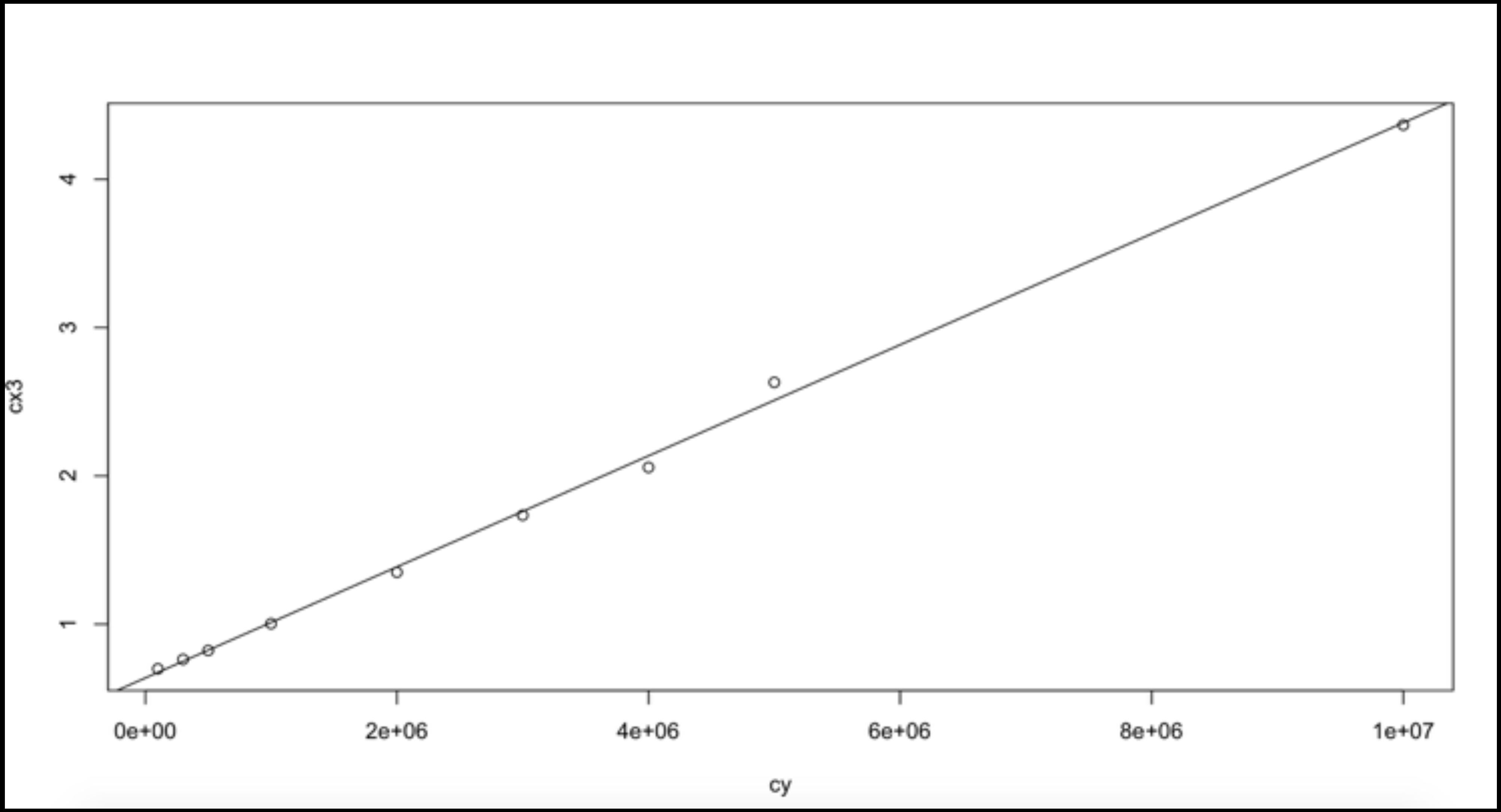
BITSORT.C

```
int main()
{    int i;
     for (i = 0; i < N; i++)
          clr(i);
/*   Replace above 2 lines with below 3 for word-parallel init
     int top = 1 + N/BITSPERWORD;
     for (i = 0; i < top; i++)
          a[i] = 0;
 */
     while (scanf("%d", &i) != EOF)
          set(i);
     for (i = 0; i < N; i++)
          if (test(i))
               printf("%d\n", i);
     return 0;
}
```

Bitsort
0.6990909
0.7627273
0.8227273
1.003636
1.350000
1.734545
2.057273
2.630909
4.366364



Bitsort
0.6990909
0.7627273
0.8227273
1.003636
1.350000
1.734545
2.057273
2.630909
4.366364



REFERENCE

- sortints.cpp: /* Copyright (C) 1999 Lucent Technologies From 'Programming Pearls' by Jon Bentley */
- qsortints.c: /* Copyright (C) 1999 Lucent Technologies. From 'Programming Pearls' by Jon Bentley. Modified by Deepak Kumar, January 2014 */
- bitsort.c: /* Copyright (C) 1999 Lucent Technologies. From 'Programming Pearls' by Jon Bentley. Modified by Deepak Kumar, January 2014 *
- bitsortgen.c/* Copyright (C) 1999 Lucent Technologies. From 'Programming Pearls' by Jon Bentley. Modified by Deepak Kumar, January 2014 *


THANK YOU