6CS005 Learning Journal - Semester 1 2019/20

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1 POSIX Threads

1.1 Password Cracking

Insert a table of 10 running times and the mean running time.

No.	Nanoseconds	Seconds
1.	508144274294	508.144274294
2.	504983681529	504.983681529
3.	507994538268	507.994538268
4.	508551703597	508.551703597
5.	506553751119	506.553751119
6.	507681018088	507.681018088
7.	505525211300	505.525211300
8.	505730813811	505.730813811
9.	506607479040	506.607479040
10.	505055320878	505.055320878
Meantime in Nanoseconds	506682779191.4	
Meantime in Seconds		

Insert a paragraph that hypothesises how long it would take to run if the number of initials were to be increased to 3. Include your calculations.

If we increase from two initials to three initial the running time will be increases because we have added another loop which takes more time to run the loop.

```
1.  #include <stdio.h>
2.  #include <string.h>
3.  #include <stdlib.h>
4.  #include <crypt.h>
5.  #include <time.h>
6.  #include <math.h>
7.
8.
9.
10. int n_passwords = 4;
11.
12. char *encrypted_passwords[] = {
13.   "$6$KB$t7URKN07IpCV3VKvOB827yLWDjxPsdVJJI9V5yqRbuEmepRDqjGAlapr2G4s6gKTCi82Hc1/NW/JR7v53WyXj/",
14.   "$6$KB$z1NK/wrNzMrVL2aZ4wbqldqS6GA3bgIehxART1ChD05bD5UZl3sXrN7eNsXr1Xbf71UegPUhPicQNwBT6fgyM1",
15.   "$6$KB$DOBoXJMpjGBLxcJePibVbPUiC2GdZgKinYenlPygdimi.TQ5dr.ZTgD01xLHXT6BT7beWXmFL6b/R8FxO/f4z.",
```

```
  "$6$KB$QWkb1xmXZGyP8XQTuLWpatEVtuWr6zw9o7CFDNO6bhGogAEXy9By1Ks6hzk.peTt3cwC.0NBkixzm.ial8nUZ0"
};


void substr(char *dest, char *src, int start, int length){
  memcpy(dest, src + start, length);
  *(dest + length) = '\0';
}


void crack(char *salt_and_encrypted){
  int x, d, f, b;
  char salt[7];
  char plain[7];
  char *enc;
  int count = 0;

  substr(salt, salt_and_encrypted, 0, 6);

  for(x='A'; x<='Z'; x++){
    for(d='A'; d<='Z'; d++){
      for(f='A'; f<='Z'; f++){
    for(b=0; b<=99; b++){
        sprintf(plain, "%c%c%c%02d", x, d, f, b);
        enc = (char *) crypt(plain, salt);
        count++;
        if(strcmp(salt_and_encrypted, enc) == 0){
          printf("#%-8d%s %s\n", count, plain, enc);

      }
else{printf("%-8d%s %s\n", count, plain, enc);}
        }
      }
    }
  }
  printf("%d solutions explored\n", count);
}

int time_difference(struct timespec *start, struct timespec *finish,
                              long long int *difference) {
  long long int ds =  finish->tv_sec - start->tv_sec;
  long long int dn =  finish->tv_nsec - start->tv_nsec;

  if(dn < 0 ) {
    ds--;
```

```
    dn += 1000000000;
  }
  *difference = ds * 1000000000 + dn;
  return !(*difference > 0);
}


int main(int argc, char *argv[]){
  struct timespec start, finish;
  long long int time_elapsed;

  clock_gettime(CLOCK_MONOTONIC, &start);
  int i;

  for(i=0;i<n_passwords;i<i++) {
    crack(encrypted_passwords[i]);
  }

   clock_gettime(CLOCK_MONOTONIC, &finish);
  time_difference(&start, &finish, &time_elapsed);
  printf("Time elapsed was %lldns or %0.9lfs\n", time_elapsed,
         (time_elapsed/1.0e9));

  return 0;
}
```

Explain your results of running your 3 initial password cracker with relation to your earlier hypothesis.

```
#189879  CVA78 $6$KB$t7URKN07IpCV3VKvOB827yLWDjxPsdVJJI9V5yqRbuEmepRDqjGAlapr2G4s6gKTCi82Hc1/NW/JR7v53WyXj/

#382384  FRB83 $6$KB$z1NK/wrNzMrVL2aZ4wbqldqS6GA3bgIehxART1ChD05bD5UZl3sXrN7eNsXr1Xbf71UegPUhPicQNwBT6fgyM1

#452405  GSA04 $6$KB$DOBoXJMpjGBLxcJePibVbPUiC2GdZgKinYenlPygdimi.TQ5dr.ZTgD01xLHXT6BT7beWXmFL6b/R8FxO/f4z.

#1287246 TBC45 $6$KB$QWkb1xmXZGyP8XQTuLWpatEVtuWr6zw9o7CFDNO6bhGogAEXy9By1Ks6hzk.peTt3cwC.0NBkixzm.ial8nUZ0


Time elapsed was 13134120445358ns or 13134.120445358s
```

Paste your source code for your multithread password cracker here

```c
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <crypt.h>
#include <time.h>
#include <pthread.h>


int n_passwords = 4;

char *encrypted_passwords[] = {

"$6$KB$6SsUGf4Cq7/Oooym9WWQN3VKeo2lynKV9gXVyEG4HvYy1UFRx.XAye89TLp/OTcW7cGpf9UlU0F.cK/S9CfZn1",

"$6$KB$1ocIiuN6StvEskjsYoYBid/gy8zXybieNCm9uM94nRw.ik9I04W3DJg0E52dswnozLmM0BIlzRZxgd.TleBwp1",

"$6$KB$L4mWcpv6rMAbZdxfSsuAL2UZhbJ4vSGAAxk.vEcRKvIuPpwcSRKHzi3BXzWQWaH1p1ubwaFl.06CRQv6bVo3M1",

"$6$KB$OpOIZac00sMBfYemANRTO3lKNZCFLegKAMakI3i2fk78/vZgo01X5mdG/1R1K0Ohs0V1AuxfOK7KY.th3dInb0"
};

void substr(char *dest, char *src, int start, int length){
  memcpy(dest, src + start, length);
  *(dest + length) = '\0';
}
void pass()
{
  int i;
pthread_t thread_1, thread_2;

    void *kernel_function_1();
    void *kernel_function_2();
for(i=0;i<n_passwords;i<i++) {


    pthread_create(&thread_1, NULL,kernel_function_1, encrypted_passwords[i]);
    pthread_create(&thread_2, NULL,kernel_function_2, encrypted_passwords[i]);

    pthread_join(thread_1, NULL);
    pthread_join(thread_2, NULL);
 }
}
```

```
43.
44. void *kernel_function_1(void *salt_and_encrypted){
45.   int b, i, s;
46.   char salt[7];
47.   char plain[7];
48.   char *enc;
49.   int count = 0;
50.
51.   substr(salt, salt_and_encrypted, 0, 6);
52.
53.   for(b='A'; b<='M'; b++){
54.     for(i='A'; i<='Z'; i++){
55.       for(s=0; s<=99; s++){
56.         sprintf(plain, "%c%c%02d", b,i,s);
57.         enc = (char *) crypt(plain, salt);
58.         count++;
59.         if(strcmp(salt_and_encrypted, enc) == 0){
60.           printf("#%-8d%s %s\n", count, plain, enc);
61.         }
62.       }
63.     }
64.   }
65.   printf("%d solutions explored\n", count);
66. }
67.
68.
69. void *kernel_function_2(void *salt_and_encrypted){
70.   int b, i, s;     // Loop counters
71.   char salt[7];    // String used in hahttps://www.youtube.com/watch?v=L8yJjIGleMwshing the password. Need space
72.   char plain[7];   // The combination of letters currently being checked
73.   char *enc;       // Pointer to the encrypted password
74.   int count = 0;   // The number of combinations explored so far
75.
76.   substr(salt, salt_and_encrypted, 0, 6);
77.
78.   for(b='N'; b<='Z'; b++){
79.     for(i='A'; i<='Z'; i++){
80.       for(s=0; s<=99; s++){
81.         sprintf(plain, "%c%c%02d", b,i,s);
82.         enc = (char *) crypt(plain, salt);
83.         count++;
84.         if(strcmp(salt_and_encrypted, enc) == 0){
85.           printf("#%-8d%s %s\n", count, plain, enc);
86.         }
87.       }
88.     }
89.   }
```

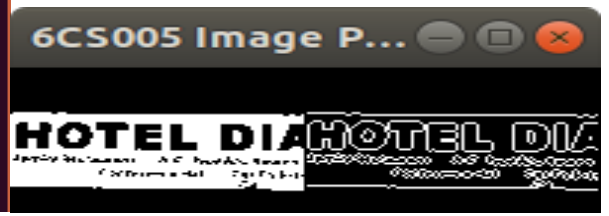
```
90.   printf("%d solutions explored\n", count);
91. }
92.
93. //Calculating time
94.
95. int time_difference(struct timespec *start, struct timespec *finish, long long int *difference)
96.  {
97.       long long int ds =  finish->tv_sec - start->tv_sec;
98.       long long int dn =  finish->tv_nsec - start->tv_nsec;
99.
100.             if(dn < 0 ) {
101.               ds--;
102.               dn += 1000000000;
103.         }
104.             *difference = ds * 1000000000 + dn;
105.             return !(*difference > 0);
106.       }
107.       int main(int argc, char *argv[])
108.       {
109.
110.           struct timespec start, finish;
111.           long long int time_elapsed;
112.
113.           clock_gettime(CLOCK_MONOTONIC, &start);
114.
115.
116.
117.                 pass();
118.
119.           clock_gettime(CLOCK_MONOTONIC, &finish);
120.             time_difference(&start, &finish, &time_elapsed);
121.             printf("Time elapsed was %lldns or %0.9lfs\n", time_elapsed,
122.                                                 (time_elapsed/1.0e9));
123.         return 0;
124.       }
```

Write a paragraph that compares the original results with those of your multithread password cracker.

1.2 Image Processing

Insert the image displayed by your program

```
bishrut@herald-OptiPlex-3050:~/Downloads/bishrut hpc/2a1$ cc -o ip_coursework_06
9 ip_coursework_069.c -lglut -lGL -lm
bishrut@herald-OptiPlex-3050:~/Downloads/bishrut hpc/2a1$ chmod a+x mr.py
bishrut@herald-OptiPlex-3050:~/Downloads/bishrut hpc/2a1$ ./mr.py ./ip_coursewor
k_069|grep Time>imgpro2a.csv
bishrut@herald-OptiPlex-3050:~/Downloads/bishrut hpc/2a1$
```




```
Insert the code for your multithreaded edge detector here
```

```c
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <GL/glut.h>
#include <GL/gl.h>
#include <malloc.h>
#include <signal.h>
#include <pthread.h>
#define width 100
#define height 72
typedef struct argument_t{
    int start;
    int stride;
}Bis_thread;

unsigned char image[], results[width * height];

void detect_edges(unsigned char *in, unsigned char *out,Bis_thread *args) {
  int i;
  int n_pixels = width * height;

  for(i=args->start;i<n_pixels;i+=args->stride) {
    int x, y;
    int b, d, f, h;
    int r;

    y = i / width;
```

```
    x = i - (width * y);

    if (x == 0 || y == 0 || x == width - 1 || y == height - 1) {
      results[i] = 0;
    } else {
      b = i + width;
      d = i - 1;
      f = i + 1;
      h = i - width;

      r = (in[i] * 4) + (in[b] * -1) + (in[d] * -1) + (in[f] * -1)
          + (in[h] * -1);

      if (r > 0) {
        out[i] = 255;
      } else {
        out[i] = 0;
      }
    }
  }
}

void tidy_and_exit() {
  exit(0);
}

void sigint_callback(int signal_number){
  printf("\nInterrupt from keyboard\n");
  tidy_and_exit();
}

static void display() {
  glClear(GL_COLOR_BUFFER_BIT);
  glRasterPos4i(-1, -1, 0, 1);
  glDrawPixels(width, height, GL_LUMINANCE, GL_UNSIGNED_BYTE, image);
  glRasterPos4i(0, -1, 0, 1);
  glDrawPixels(width, height, GL_LUMINANCE, GL_UNSIGNED_BYTE, results);
  glFlush();
}
void *detector(void *args){

detect_edges(image,results,args);

}
static void key_pressed(unsigned char key, int x, int y) {
  switch(key){
    case 27:
```

```
75.       tidy_and_exit();
76.       break;
77.     default:
78.       printf("\nPress escape to exit\n");
79.       break;
80.   }
81. }
82. int time_difference(struct timespec *start, struct timespec *finish,
83.                       long long int *difference) {
84.   long long int ds =  finish->tv_sec - start->tv_sec;
85.   long long int dn =  finish->tv_nsec - start->tv_nsec;
86.
87.   if(dn < 0 ) {
88.     ds--;
89.     dn += 1000000000;
90.   }
91.   *difference = ds * 1000000000 + dn;
92.   return !(*difference > 0);
93. }
94.
95.
96. int main(int argc, char **argv) {
97.
98.   struct timespec start, finish;
99.   long long int time_elapsed;
100.
101.     clock_gettime(CLOCK_MONOTONIC, &start);
102.
103.   printf("image dimensions %dx%d\n", width, height);
104.     pthread_t t1, t2, t3, t4;
105.
106.     Bis_thread t1_arguments;
107.     t1_arguments.start = 0;
108.     t1_arguments.stride = 4;
109.
110.     Bis_thread t2_arguments;
111.     t2_arguments.start = 1;
112.     t2_arguments.stride = 4;
113.
114.     Bis_thread t3_arguments;
115.     t3_arguments.start = 2;
116.     t3_arguments.stride = 4;
117.
118.     Bis_thread t4_arguments;
119.     t4_arguments.start = 3;
120.     t4_arguments.stride = 4;
121.
```

```
122.
123.     pthread_create(&t1, NULL, detector, &t1_arguments);
124.     pthread_create(&t2, NULL, detector, &t2_arguments);
125.     pthread_create(&t3, NULL, detector, &t3_arguments);
126.     pthread_create(&t4, NULL, detector, &t4_arguments);
127.
128.     pthread_join(t1, NULL);
129.     pthread_join(t2, NULL);
130.     pthread_join(t3, NULL);
131.     pthread_join(t4, NULL);
132.
133.     clock_gettime(CLOCK_MONOTONIC, &finish);
134.     time_difference(&start, &finish, &time_elapsed);
135.     printf("Time elapsed was %lldns or %0.9lfs\n", time_elapsed,
136.            (time_elapsed/1.0e9));
137.
138.     signal(SIGINT, sigint_callback);
139.
140.     printf("image dimensions %dx%d\n", width, height);
141.
142.
143.     glutInit(&argc, argv);
144.     glutInitWindowSize(width * 2,height);
145.     glutInitDisplayMode(GLUT_SINGLE | GLUT_LUMINANCE);
146.
147.     glutCreateWindow("6CS005 Image Progessing Courework");
148.     glutDisplayFunc(display);
149.     glutKeyboardFunc(key_pressed);
150.     glClearColor(0.0, 1.0, 0.0, 1.0);
151.
152.     glutMainLoop();
153.
154.     tidy_and_exit();
155.
156.   }
157.
158.   unsigned char image[] = {0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
159.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
160.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
161.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
162.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
163.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
164.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
165.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
166.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
167.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
168.     0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
```

```
169.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
170.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
171.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
172.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
173.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
174.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
175.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
176.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
177.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
178.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
179.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
180.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
181.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
182.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
183.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
184.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
185.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
186.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
187.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
188.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
189.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
190.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
191.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
192.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
193.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
194.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
195.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
196.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
197.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
198.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
199.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
200.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
201.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
202.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
203.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
204.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
205.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
206.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
207.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
208.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
209.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
210.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
211.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
212.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
213.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
214.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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404.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
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406.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
407.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
408.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
409.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
410.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
411.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
412.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
413.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
414.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
415.      255,255,255,255,255,255,255,255,255,255,255,0,0,255,255,0,0,255,255,0,
416.      255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,255,255,255,0,
417.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
418.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
419.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
420.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
421.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
422.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
423.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
424.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
425.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
426.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
427.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
428.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
429.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
430.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
431.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
432.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
433.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
434.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
435.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
436.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
437.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
438.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
439.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
440.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
441.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
442.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
443.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
444.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
445.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
446.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
447.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
448.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
449.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
450.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
```

```
451.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
452.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
453.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
454.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
455.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
456.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
457.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
458.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
459.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
460.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
461.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
462.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
463.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
464.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
465.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
466.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
467.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
468.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
469.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
470.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
471.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
472.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
473.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
474.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
475.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
476.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
477.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
478.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
479.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
480.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
481.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
482.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
483.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
484.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
485.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
486.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
487.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
488.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
489.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
490.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
491.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
492.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
493.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
494.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
495.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
496.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
497.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
```

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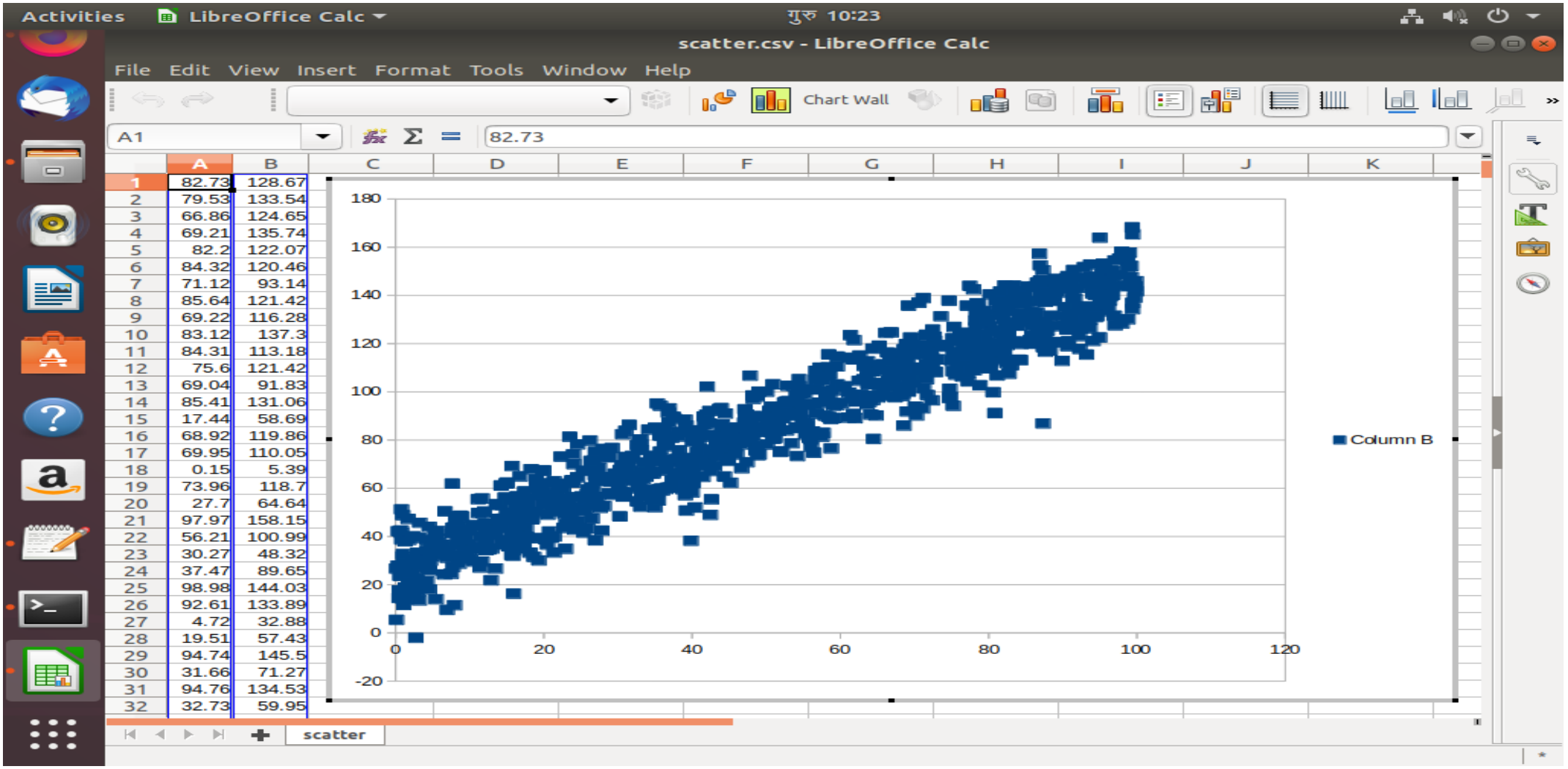
498.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
499.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
500.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
501.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
502.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
503.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
504.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
505.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
506.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
507.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
508.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
509.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
510.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
511.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
512.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
513.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
514.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
515.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
516.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
517.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
518.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
519.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
520.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
521.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
522.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
523.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
524.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
525.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
526.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
527.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
528.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
529.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
530.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
531.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
532.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
533.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
534.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
535.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
536.      0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
537.    };
```

Insert a table that has columns containing running times for the original program and your multithread version. Mean running times should be included at the bottom of the columns.

Insert an explanation of the results presented in the above table.

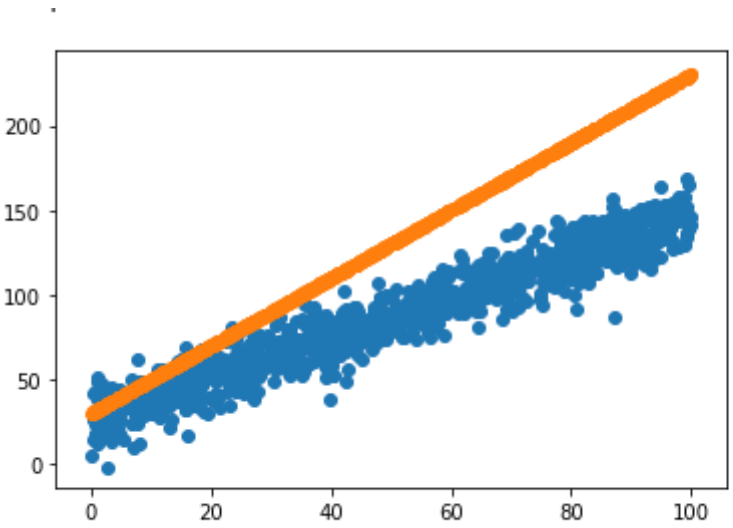
1.3 Linear Regression

Insert a scatter plot of your data.

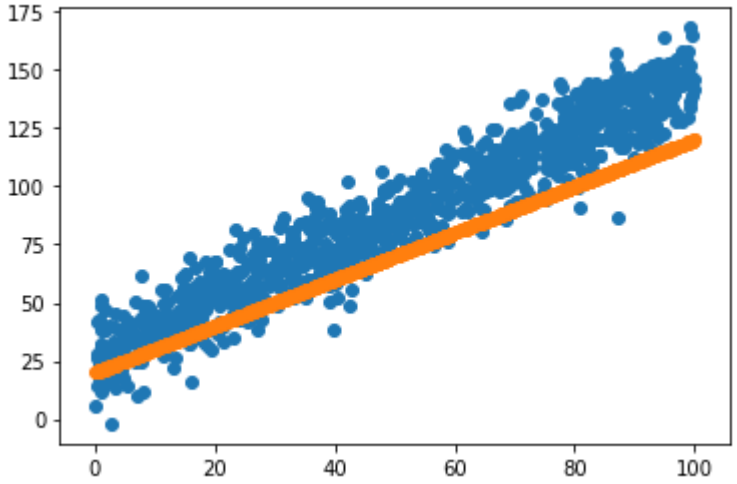


Have 3 guesses at the optimum values for m and c and present them in a graph that overlays your data.

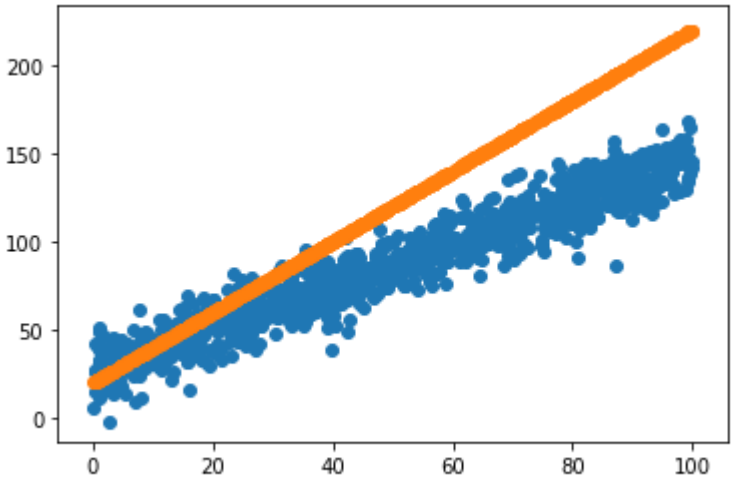
Guess1:



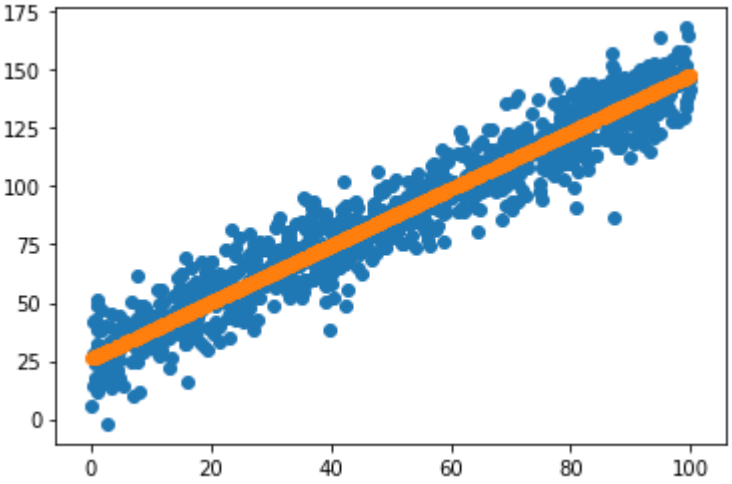
Guess2:



Guess3:



Insert a graph that presents your data with the solution overlaid.



Insert a comment that compares your guesses with the solution found.

Paste your source code for your multithread linear regression program here.

```c
#include <stdio.h>
#include <math.h>
#include <time.h>
#include <pthread.h>
int i;
  double bm = 1.3;
  double bc = 10;
  double be;
  double dm[8];
  double dc[8];
  double e[8];
  double step = 0.01;
  double best_error = 999999999;
  int best_error_i;
  int minimum_found = 0;
  double om[] = {0,1,1, 1, 0,-1,-1,-1};
  double oc[] = {1,1,0,-1,-1,-1, 0, 1};

typedef struct point_t {
  double x;
  double y;
} point_t;

int n_data = 1000;
point_t data[];

double residual_error(double x, double y, double m, double c) {
  double e = (m * x) + c - y;
  return e * e;
}

double rms_error(double m, double c) {
  int i;
  double mean;
  double error_sum = 0;

  for(i=0; i<n_data; i++) {
    error_sum += residual_error(data[i].x, data[i].y, m, c);
  }
```

```
40.
41.   mean = error_sum / n_data;
42.
43.   return sqrt(mean);
44. }
45. int time_difference(struct timespec *start, struct timespec *finish, long long int *difference)
46. {
47.   long long int ds =  finish->tv_sec - start->tv_sec;
48.   long long int dn =  finish->tv_nsec - start->tv_nsec;
49.
50.   if(dn < 0 ) {
51.     ds--;
52.     dn += 1000000000;
53.   }
54.   *difference = ds * 1000000000 + dn;
55.   return !(*difference > 0);
56. }
57.
58. void *linear_regression_thread(void *args){
59.
60.   int *a = args;
61.   int i = *a;
62.
63.   dm[i] = bm +(om[i] * step);
64.       dc[i] = bc + (oc[i] * step);
65.   e[i] = rms_error(dm[i], dc[i]);
66.   if(e[i] < best_error) {
67.   best_error = e[i];
68.   best_error_i = i;
69.   pthread_exit(NULL);
70.   }
71. }
72.
73. int main() {
74.    struct timespec start, finish;
75.   long long int time_elapsed;
76.   clock_gettime(CLOCK_MONOTONIC, &start);
77.
78.   int i;
79.   pthread_t p_threads[8];
80.
81.   be = rms_error(bm, bc);
82.
83.   while(!minimum_found) {
84.     for(i=0;i<8;i++) {
85.       pthread_create(&p_threads[i], NULL, (void*)linear_regression_thread, &i);
86.       pthread_join(p_threads[i], NULL);
```

```
    }
    if(best_error < be) {
      be = best_error;
      bm = dm[best_error_i];
      bc = dc[best_error_i];
    } else {
      minimum_found = 1;
    }
  }
  printf("minimum m,c is %lf,%lf with error %lf\n", bm, bc, be);
  clock_gettime(CLOCK_MONOTONIC, &finish);
  time_difference(&start, &finish, &time_elapsed);
  printf("Time elapsed was %lldns or %0.9lfs\n", time_elapsed,
                (time_elapsed/1.0e9));

        return 0;
      }
      point_t data[] = {
        {82.73,128.67},{79.53,133.54},{66.86,124.65},{69.21,135.74},
        {82.20,122.07},{84.32,120.46},{71.12,93.14},{85.64,121.42},
        {69.22,116.28},{83.12,137.30},{84.31,113.18},{75.60,121.42},
        {69.04,91.83},{85.41,131.06},{17.44,58.69},{68.92,119.86},
        {69.95,110.05},{ 0.15, 5.39},{73.96,118.70},{27.70,64.64},
        {97.97,158.15},{56.21,100.99},{30.27,48.32},{37.47,89.65},
        {98.98,144.03},{92.61,133.89},{ 4.72,32.88},{19.51,57.43},
        {94.74,145.50},{31.66,71.27},{94.76,134.53},{32.73,59.95},
        {32.64,54.53},{38.78,69.06},{91.47,150.49},{77.99,119.35},
        {33.38,65.87},{79.28,123.62},{39.69,72.53},{95.47,140.97},
        {82.64,137.69},{25.53,51.33},{68.58,85.98},{92.25,132.34},
        {74.79,101.30},{ 1.32,18.87},{53.85,95.13},{78.75,128.26},
        { 2.91,21.77},{90.68,128.55},{11.44,35.27},{30.72,56.54},
        {49.06,74.08},{49.09,83.45},{62.54,104.58},{38.83,72.26},
        {78.43,130.83},{69.49,122.49},{27.27,56.35},{80.06,131.95},
        { 5.73,39.00},{80.21,140.42},{ 8.47,36.12},{86.98,152.43},
        {64.26,108.56},{95.74,133.36},{15.06,48.67},{31.96,72.31},
        {95.27,141.34},{61.10,89.26},{27.51,68.47},{26.48,60.30},
        {92.61,128.38},{ 8.25,47.51},{90.69,118.91},{45.40,79.96},
        {23.59,53.12},{46.71,68.27},{21.15,50.29},{27.99,76.29},
        { 7.75,43.57},{13.70,43.56},{74.85,97.83},{50.93,103.11},
        {33.80,64.85},{80.99,125.37},{92.41,126.27},{92.61,134.36},
        {34.70,55.32},{35.07,55.04},{86.87,157.26},{41.99,90.46},
        {16.27,44.43},{36.31,83.84},{22.35,73.11},{89.11,127.19},
        {56.11,77.28},{51.90,75.07},{35.74,94.18},{10.66,29.60},
        {61.27,114.15},{77.55,117.04},{61.17,99.68},{15.54,55.33},
        {91.99,143.18},{12.91,21.82},{48.52,89.94},{54.88,90.86},
        {73.59,131.33},{ 5.49,13.95},{92.31,147.29},{48.50,89.49},
        {40.02,58.26},{48.22,81.96},{17.08,52.59},{34.27,66.17},
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134.         {59.06,94.26},{92.71,134.53},{37.70,65.30},{77.11,111.38},
135.         {43.27,74.12},{79.71,123.45},{ 0.86,38.69},{ 3.00,17.76},
136.         {56.03,80.33},{17.66,43.27},{18.39,47.08},{31.08,83.84},
137.         {32.64,77.85},{51.68,84.57},{78.46,134.18},{ 9.57,40.28},
138.         {68.38,98.26},{30.29,67.59},{86.15,131.86},{16.82,64.91},
139.         { 3.35,20.88},{65.78,98.73},{50.70,90.92},{38.26,71.11},
140.         {85.52,132.23},{44.06,83.02},{44.09,86.42},{81.86,114.30},
141.         {33.98,69.09},{93.80,147.73},{59.58,103.07},{98.75,154.73},
142.         {88.98,120.59},{78.08,109.00},{82.77,133.94},{76.49,106.31},
143.         {55.38,85.71},{46.56,79.57},{83.92,141.58},{81.38,133.52},
144.         { 4.88,35.01},{ 4.57,17.99},{57.96,90.07},{33.42,63.80},
145.         { 9.95,34.53},{47.14,92.75},{63.17,105.19},{95.01,163.93},
146.         {30.36,57.81},{ 2.46,23.97},{69.75,115.88},{64.85,111.01},
147.         {25.18,56.58},{69.84,104.78},{40.43,51.98},{75.61,107.05},
148.         {36.75,69.37},{50.08,100.02},{64.97,103.68},{41.72,86.64},
149.         { 1.70,47.26},{99.93,141.75},{24.57,64.51},{75.23,116.35},
150.         { 1.95,18.53},{78.84,102.70},{67.38,97.71},{55.35,82.37},
151.         {58.10,100.09},{53.10,96.07},{41.24,83.81},{68.86,111.98},
152.         {87.36,86.88},{54.06,98.42},{64.12,90.56},{11.77,49.66},
153.         {99.43,134.33},{55.24,99.18},{56.44,74.73},{39.47,62.99},
154.         { 8.94,48.15},{92.91,130.45},{87.68,138.76},{80.37,116.69},
155.         {56.72,108.65},{ 0.76,24.26},{26.98,75.13},{ 0.39,42.16},
156.         {81.99,138.50},{88.32,117.16},{51.01,87.42},{21.38,55.45},
157.         {72.66,122.82},{18.04,53.56},{11.22,49.73},{36.75,60.26},
158.         {64.81,90.19},{72.72,121.14},{24.03,74.08},{41.38,81.38},
159.         {62.79,98.75},{63.66,109.17},{91.12,143.91},{ 7.41,34.06},
160.         {94.05,131.99},{53.12,90.28},{68.31,114.79},{25.33,67.23},
161.         {42.34,86.91},{94.61,131.38},{43.78,73.28},{50.18,78.10},
162.         {81.64,135.88},{11.27,44.45},{41.03,76.34},{21.25,57.54},
163.         {29.23,57.27},{35.74,75.16},{ 0.91,14.33},{30.08,59.05},
164.         {23.99,56.25},{90.79,120.98},{99.22,152.22},{94.21,143.09},
165.         {19.35,30.03},{82.04,113.25},{79.22,113.69},{83.40,144.06},
166.         {55.82,80.85},{42.49,48.94},{17.60,55.62},{35.65,81.91},
167.         {82.50,135.41},{81.15,114.46},{53.47,78.67},{44.30,73.73},
168.         {32.88,80.28},{99.26,147.55},{76.32,110.24},{78.97,110.27},
169.         {18.08,47.48},{87.01,140.40},{56.25,83.61},{42.62,55.40},
170.         {15.95,16.25},{47.85,106.69},{ 6.61,35.83},{66.38,116.30},
171.         {94.97,122.56},{42.29,73.37},{31.48,67.15},{69.67,105.40},
172.         {30.41,65.31},{ 2.98,19.40},{ 8.12,48.34},{80.41,127.03},
173.         {63.68,112.61},{24.60,78.23},{77.61,123.49},{39.87,38.20},
174.         {77.80,109.59},{58.53,107.63},{23.97,62.36},{ 7.77,27.38},
175.         { 0.80,41.55},{ 6.45,32.91},{45.32,82.24},{35.56,59.56},
176.         {65.05,97.68},{62.21,96.14},{86.61,121.99},{87.91,125.40},
177.         {48.08,88.87},{ 2.41,40.02},{69.55,119.31},{22.07,61.86},
178.         {61.87,121.40},{82.50,119.46},{26.97,38.40},{31.53,86.30},
179.         { 1.81,38.57},{72.57,108.34},{88.88,139.23},{63.90,95.79},
180.         {93.29,135.35},{86.26,143.55},{63.62,94.76},{20.24,38.84},
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        {16.23,48.64},{72.87,108.22},{16.26,51.25},{37.86,66.06},
        {57.53,81.37},{61.66,97.20},{49.48,84.98},{95.20,142.45},
        {12.10,45.25},{47.79,84.80},{17.29,48.98},{47.11,87.23},
        {85.74,119.95},{89.94,142.94},{97.68,155.27},{78.73,123.81},
        {51.65,85.91},{52.82,96.05},{50.95,93.50},{16.14,37.21},
        {16.73,41.57},{57.25,95.50},{78.47,136.77},{42.35,75.64},
        {93.24,135.04},{12.56,38.20},{21.40,62.92},{70.60,136.98},
        {44.04,83.57},{ 6.43,36.61},{12.01,50.32},{79.61,119.78},
        {43.05,69.07},{14.42,53.01},{51.68,83.82},{25.59,55.77},
        { 9.14,31.58},{37.24,80.94},{15.73,69.21},{71.54,123.11},
        { 1.26,25.72},{ 4.25,38.46},{21.42,39.99},{44.12,79.01},
        {31.12,64.63},{85.27,143.62},{43.25,79.30},{77.27,104.30},
        {47.34,83.76},{90.57,125.82},{17.35,36.40},{82.01,130.41},
        {81.58,124.10},{68.62,117.62},{47.48,79.29},{ 4.30,26.77},
        { 6.94,32.22},{11.71,55.76},{22.62,54.74},{58.43,89.61},
        {69.10,111.51},{56.77,101.10},{67.10,102.75},{93.20,144.51},
        {83.61,128.56},{71.97,116.09},{75.19,122.16},{48.03,79.67},
        {97.95,143.80},{92.27,123.08},{23.88,63.39},{79.15,115.57},
        {24.42,51.27},{12.58,34.65},{46.58,78.16},{ 1.29,37.96},
        {17.09,45.61},{12.45,40.77},{82.75,107.46},{52.15,75.34},
        {39.51,68.51},{31.71,64.23},{39.36,72.00},{12.16,37.99},
        {83.13,127.76},{42.25,73.17},{45.32,77.14},{20.52,36.60},
        { 7.99,11.50},{23.34,55.47},{25.87,54.36},{78.73,112.49},
        {55.60,94.90},{31.98,73.40},{85.93,137.12},{58.56,97.64},
        {88.16,120.43},{78.65,136.60},{25.93,43.32},{84.83,136.32},
        {68.09,102.12},{68.36,111.80},{39.80,69.69},{ 0.38,27.89},
        { 4.49,27.85},{32.53,66.32},{54.23,97.63},{19.98,67.32},
        {90.62,143.43},{18.31,67.91},{95.66,146.41},{95.41,149.68},
        {71.64,111.15},{23.02,44.96},{97.06,154.54},{41.58,75.95},
        {79.80,130.01},{74.55,119.44},{72.19,113.27},{70.01,106.48},
        {75.24,94.18},{19.82,60.09},{96.31,137.91},{ 2.21,27.44},
        {40.52,70.36},{ 2.40,29.12},{35.24,57.25},{26.38,71.34},
        {26.02,59.48},{34.73,66.07},{45.15,78.23},{ 9.35,32.58},
        {19.37,57.18},{ 9.51,31.70},{15.03,49.81},{85.08,140.35},
        { 3.23,13.46},{58.26,108.47},{ 4.84,31.78},{49.49,83.50},
        {35.55,70.67},{26.51,55.44},{20.12,53.39},{72.73,119.37},
        {31.04,72.96},{30.66,58.35},{ 2.96,33.18},{18.68,31.50},
        {91.41,138.24},{44.67,81.81},{81.57,135.26},{ 0.17,26.66},
        {49.03,100.11},{54.47,102.27},{61.78,113.45},{22.67,59.51},
        {89.80,143.05},{33.05,78.20},{67.76,108.19},{ 7.64,41.18},
        {36.91,87.28},{95.44,147.27},{52.76,94.34},{ 3.52,29.51},
        {87.39,118.48},{41.48,64.71},{ 1.44,14.21},{95.04,136.99},
        {71.77,115.75},{23.39,47.58},{62.66,115.03},{15.98,34.38},
        {29.06,62.77},{ 2.94,28.25},{71.50,119.18},{65.24,119.14},
        {30.65,82.39},{16.36,38.82},{ 0.98,48.82},{33.19,56.41},
        {27.49,64.34},{53.69,102.47},{28.15,52.58},{40.21,66.07},
        {50.56,86.39},{74.71,97.44},{24.72,46.29},{48.05,80.63},
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228.         {34.99,52.13},{66.75,115.96},{17.62,49.17},{98.99,157.80},
229.         {37.96,72.18},{56.88,105.06},{48.27,97.04},{71.18,138.90},
230.         {46.35,82.02},{10.43,44.65},{24.14,42.85},{82.21,144.13},
231.         {96.85,148.15},{93.68,126.32},{33.02,61.55},{66.73,108.51},
232.         {83.89,136.35},{80.85,91.16},{79.21,128.88},{84.37,119.84},
233.         {38.41,71.48},{47.49,85.53},{ 1.54,24.44},{68.32,106.44},
234.         {22.82,54.16},{ 2.65,16.35},{19.91,53.53},{12.99,34.98},
235.         {30.87,57.17},{44.10,83.88},{15.84,31.99},{36.46,59.74},
236.         {26.25,79.73},{79.12,132.06},{86.26,132.45},{ 0.61,23.61},
237.         {33.94,59.37},{99.92,145.88},{26.20,53.99},{69.77,115.40},
238.         {69.07,107.00},{ 1.89,17.20},{38.25,81.40},{27.08,62.96},
239.         {23.09,53.98},{55.56,86.93},{ 6.68,50.41},{22.86,49.26},
240.         {17.25,50.25},{19.01,50.16},{35.07,85.09},{59.08,89.15},
241.         {87.02,128.83},{ 1.57,27.68},{97.76,148.25},{70.78,108.00},
242.         {38.01,65.83},{96.41,139.67},{ 2.86,22.44},{27.05,53.00},
243.         {90.99,134.97},{86.60,145.27},{54.66,99.42},{67.61,107.07},
244.         {85.16,137.50},{87.64,144.60},{14.69,36.65},{16.08,49.31},
245.         {14.45,44.07},{65.91,98.39},{50.74,90.72},{ 6.98,31.11},
246.         {52.76,83.96},{ 8.03,43.93},{17.58,52.58},{33.63,59.04},
247.         {87.65,137.34},{77.97,142.54},{30.56,69.47},{59.61,114.61},
248.         {14.05,53.07},{87.65,116.66},{33.19,75.96},{31.87,66.95},
249.         {25.89,57.59},{48.60,75.67},{80.25,109.89},{ 6.61,24.27},
250.         { 4.56,44.00},{40.17,62.33},{92.32,117.73},{75.07,112.71},
251.         {17.10,35.12},{39.06,66.60},{ 4.26,34.01},{52.95,102.49},
252.         {45.73,76.57},{ 4.72,29.94},{ 2.01,17.54},{39.08,88.44},
253.         {82.94,141.75},{44.51,90.97},{27.27,63.14},{60.16,95.38},
254.         {41.26,72.59},{66.50,104.49},{58.37,110.13},{62.11,96.01},
255.         {70.30,90.15},{18.47,47.61},{24.80,51.82},{79.02,133.40},
256.         {96.61,147.92},{18.14,33.27},{ 0.83,51.20},{99.67,143.65},
257.         {34.07,67.38},{57.28,110.02},{35.92,59.90},{66.15,124.45},
258.         {81.82,135.08},{ 2.97,28.49},{95.97,135.79},{51.17,80.95},
259.         {91.47,142.00},{94.09,121.08},{57.70,82.98},{67.96,100.92},
260.         {81.91,132.34},{11.55,39.74},{86.59,126.05},{ 5.36,41.72},
261.         {90.86,144.15},{81.02,137.56},{35.87,81.76},{63.73,105.92},
262.         {78.29,129.54},{96.72,150.04},{14.97,61.93},{45.76,77.17},
263.         {82.69,123.95},{85.82,132.89},{85.95,127.24},{15.04,36.92},
264.         {89.91,112.87},{30.86,58.13},{ 5.77,42.22},{75.24,108.41},
265.         { 8.43,32.09},{90.70,147.99},{80.16,112.57},{42.81,73.54},
266.         {82.47,123.41},{48.23,98.48},{77.48,143.96},{ 0.48,14.50},
267.         {29.75,63.12},{88.76,137.72},{33.59,70.61},{22.74,43.51},
268.         {82.15,116.11},{89.10,120.65},{26.56,68.17},{40.72,74.98},
269.         {68.46,99.23},{34.82,66.71},{36.56,67.33},{72.32,114.23},
270.         {29.65,65.99},{44.39,64.83},{82.08,116.35},{99.73,139.12},
271.         {79.04,118.48},{20.78,42.05},{72.39,96.47},{90.62,147.11},
272.         {35.99,59.11},{50.65,83.23},{59.04,100.47},{87.01,145.78},
273.         {43.71,76.56},{95.61,151.81},{50.25,88.96},{69.64,122.07},
274.         {40.07,79.38},{82.61,133.63},{20.84,39.75},{10.28,42.50},
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275.         {47.43,70.82},{30.47,67.19},{69.16,100.10},{46.06,74.00},
276.         {93.78,152.76},{19.93,67.46},{79.61,130.88},{81.11,120.11},
277.         {76.16,123.94},{75.84,111.70},{50.97,85.30},{47.35,90.59},
278.         {93.21,115.44},{19.22,39.30},{11.67,29.58},{52.48,95.64},
279.         {38.76,59.62},{ 2.74,-2.03},{18.99,63.67},{82.38,128.08},
280.         {15.68,32.34},{39.19,83.38},{31.06,65.92},{28.91,73.05},
281.         {19.01,59.69},{76.62,117.74},{36.82,91.33},{86.28,121.19},
282.         {39.26,50.72},{41.45,70.26},{65.81,111.41},{77.09,117.88},
283.         {78.96,128.48},{16.41,56.61},{39.54,64.11},{72.45,110.54},
284.         {48.83,77.35},{27.61,51.82},{26.53,47.44},{83.06,111.09},
285.         {97.06,127.57},{89.01,146.82},{89.44,141.17},{69.18,100.25},
286.         { 1.11,11.60},{71.63,123.66},{92.93,151.73},{99.46,165.34},
287.         {36.49,71.56},{95.48,153.13},{65.33,102.37},{15.28,35.93},
288.         { 5.52,36.67},{ 0.78,42.47},{10.09,36.68},{ 5.75,37.39},
289.         {52.34,89.11},{14.55,47.37},{67.92,113.35},{36.66,77.34},
290.         {99.76,143.75},{26.67,58.72},{ 3.21,39.37},{87.70,124.12},
291.         {90.03,131.24},{51.54,91.39},{62.86,98.04},{52.75,90.87},
292.         {34.17,84.31},{62.00,89.08},{82.47,111.89},{61.38,123.48},
293.         {47.17,84.64},{20.91,53.51},{96.96,131.54},{46.06,85.14},
294.         {26.85,71.44},{91.67,138.51},{54.07,85.26},{51.63,89.63},
295.         {94.04,140.80},{67.75,107.07},{29.24,76.71},{38.29,75.78},
296.         {28.49,72.87},{60.51,102.28},{77.22,107.79},{99.25,145.86},
297.         {33.11,52.32},{72.47,125.80},{21.97,59.23},{14.25,61.11},
298.         {23.79,63.11},{77.78,109.13},{23.51,81.38},{66.92,110.89},
299.         {79.81,109.80},{56.72,94.63},{59.60,110.57},{57.68,104.54},
300.         {27.83,42.43},{47.80,87.68},{58.79,76.51},{78.33,126.71},
301.         {85.14,128.99},{71.61,116.42},{58.09,96.85},{44.89,71.34},
302.         {33.12,80.19},{98.79,130.09},{44.57,82.03},{88.63,142.61},
303.         {61.96,98.55},{58.54,106.80},{19.17,61.00},{13.51,26.68},
304.         {76.68,124.52},{82.62,138.53},{78.13,122.09},{37.10,60.33},
305.         { 8.82,48.63},{71.64,105.27},{68.44,115.07},{ 7.66,61.91},
306.         {64.37,96.58},{54.90,88.28},{78.35,133.29},{79.84,129.58},
307.         { 3.09,28.37},{48.62,76.00},{38.26,63.99},{42.05,102.17},
308.         {48.89,73.66},{54.38,100.05},{11.16,55.43},{63.24,110.69},
309.         {68.17,114.15},{68.68,109.15},{53.43,90.23},{67.45,106.67},
310.         {10.60,34.41},{56.81,90.86},{11.42,27.08},{36.93,93.13},
311.         {41.64,89.77},{69.74,103.98},{23.07,55.12},{44.98,83.65},
312.         {35.75,72.65},{14.80,56.15},{72.19,115.53},{51.10,80.69},
313.         {96.54,140.10},{15.04,62.30},{21.17,56.15},{46.42,79.63},
314.         {22.35,52.01},{35.47,54.95},{ 4.27,21.33},{84.37,139.55},
315.         {43.95,93.24},{86.56,132.82},{44.35,83.36},{76.81,114.79},
316.         { 1.05,31.66},{32.76,76.15},{83.66,120.90},{12.14,42.52},
317.         {25.85,55.83},{82.12,140.05},{75.33,126.93},{32.92,75.90},
318.         { 7.52,24.51},{25.42,41.55},{42.57,67.15},{87.36,150.38},
319.         { 0.51,17.68},{45.70,84.75},{58.74,88.68},{28.62,74.38},
320.         {73.22,113.45},{78.64,114.25},{42.40,92.03},{84.22,132.25},
321.         {54.24,73.34},{ 2.71,30.27},{54.11,84.97},{66.74,112.66},
```

```
322.         {28.80,57.88},{87.02,146.20},{32.02,63.03},{59.57,94.41},
323.         {40.46,79.73},{23.74,49.78},{87.58,140.94},{84.15,113.32},
324.         {32.48,63.48},{ 4.59,25.85},{98.00,128.35},{12.23,37.43},
325.         {66.17,102.97},{50.73,93.82},{74.68,137.79},{43.72,92.85},
326.         {53.95,91.99},{54.47,105.25},{56.70,104.89},{16.59,46.52},
327.         {71.56,115.18},{80.62,99.79},{71.29,101.42},{16.81,56.15},
328.         {48.88,84.93},{ 8.41,40.02},{93.98,147.39},{39.20,86.04},
329.         {61.75,90.80},{ 1.06,32.69},{21.40,33.33},{ 8.60,28.69},
330.         {38.80,61.88},{14.41,38.37},{40.14,70.01},{69.45,105.44},
331.         {14.41,43.93},{51.20,93.11},{39.10,57.10},{21.04,39.51},
332.         {10.12,30.43},{70.13,93.88},{ 1.74,20.56},{12.23,34.33},
333.         {98.81,151.87},{50.48,92.07},{ 6.98, 9.52},{24.08,69.94},
334.         {15.72,40.89},{83.99,127.44},{47.21,90.46},{88.31,138.70},
335.         {91.05,132.13},{45.22,62.24},{87.76,128.67},{99.37,168.24},
336.         {94.38,140.24},{31.30,67.65},{40.85,84.03},{40.91,79.56},
337.         {77.14,135.74},{50.92,80.52},{17.81,49.14},{90.30,135.15},
338.         {28.44,64.60},{49.23,85.12},{81.63,141.58},{83.04,111.19},
339.         {28.39,63.30},{ 8.61,44.11},{25.36,50.79},{51.35,93.32},
340.         {64.49,80.42},{96.17,134.31},{96.10,144.32},{47.58,83.36},
341.         {94.38,131.03},{41.97,69.05},{37.86,62.21},{26.97,65.30},
342.         {37.57,88.95},{65.08,108.58},{17.68,39.80},{63.75,103.14},
343.         {91.86,132.07},{76.35,121.19},{22.98,34.87},{96.46,140.54},
344.         { 9.38,31.40},{42.97,82.09},{20.56,49.02},{13.73,41.31},
345.         {37.35,63.18},{69.54,105.57},{38.17,83.30},{47.04,80.34},
346.         {48.79,98.00},{39.34,61.59},{82.57,125.55},{40.77,82.18},
347.         {13.62,53.38},{35.33,95.17},{95.36,148.79},{20.25,62.00},
348.         {47.48,86.54},{30.22,61.07},{83.90,120.30},{85.81,123.25},
349.         {84.29,130.44},{52.84,95.43},{96.72,140.32},{ 3.29,45.68},
350.         {71.77,98.66},{ 8.52,42.40},{22.55,54.27},{15.08,47.10},
351.         {91.29,130.23},{16.48,40.04},{44.84,72.14},{34.44,73.42},
352.         {36.26,78.30},{58.45,115.51},{96.59,150.22},{63.80,98.30},
353.         {85.92,120.14},{93.68,129.88},{74.09,119.30},{99.44,136.93},
354.         {88.39,131.55},{64.40,117.89},{13.87,47.30},{81.17,106.77}
355.       };
```

Insert a table that shows running times for the original and multithread versions.

Write a short analysis of the results.

2 CUDA

2.1 Password Cracking

```
Paste your source code for your CUDA based password cracker here
```

Insert a table that shows running times for the original and CUDA versions.

Write a short analysis of the results

2.2 Image Processing

```
Paste your source code for your CUDA based image processing.
```

Insert a table that shows running times for the original and CUDA versions.

Write a short analysis of the results

2.3 Linear Regression

Insert a table that shows running times for the original and CUDA versions.

```
Paste your source code for your CUDA based linear regression
```

Write a short analysis of the results

3 MPI

3.1 Password Cracking

```
Paste your source code for your MPI based password cracker here
```

Insert a table that shows running times for the original and MPI versions.

Write a short analysis of the results

3.2 Image Processing

```
Paste your source code for your MPI based image processor
```

Insert a table that shows running times for the original and MPI versions.

Write a short analysis of the results

3.3 Linear Regression

```
Paste your source code for your MPI based linear regression
```

Insert a table that shows running times for the original and MPI versions.

Write a short analysis of the results

4 Verbose Repository Log

```
Paste your verbose format repository log here. With subversion this can be achieved by the following:

        svn update

        svn –v log > log.txt

        gedit log.txt

Then select, copy and paste the text here
```