6CS005 Learning Journal - Semester 1 2019/20

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# POSIX Threads

## Password Cracking

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

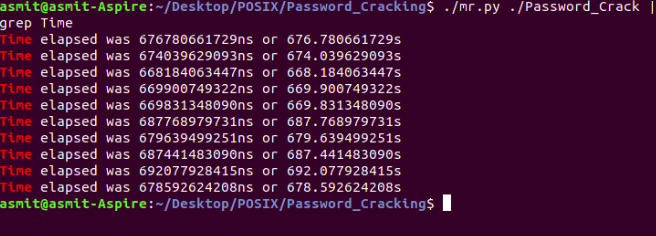


Figure 1 Executing simple program of cracking 2 initial and 2 digit password for 10 times

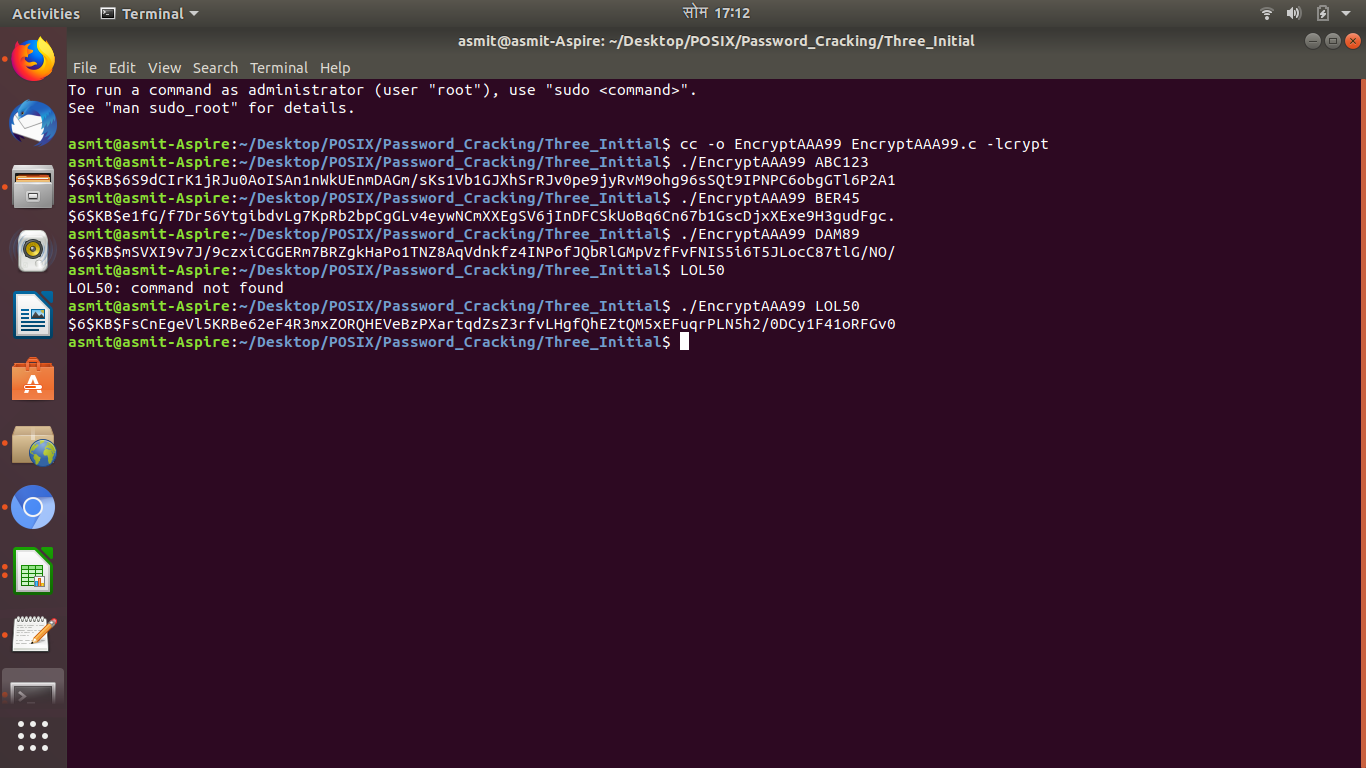
A picture containing crossword puzzle

Description automatically generated

Simple program of cracking 2 initial password was executed for 10 times to calculate mean running time that is 678.42 second.

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.

In this program we cracked 3 alphabet and 2 digit number. First we encrypted the password using SHA-512 algorithm. Proof of encrypting 3initial password is shown in figure below.



It would take more time than two initial if the number of initials were to be increased to 3. From figure:2 it is clear that it takes about 6 minute to run two initial program but if the initial were increased it is obvious to increase in time as the program will go through each and every for loops. It would take 26 time more if the initial were to be increased to 3 that means it will take about 678\*26 =17,628 second time for completing 3 initial program.

Calculation,

Estimated time= original time \* 26 = 678 \*26=17,628 second

1. #include <stdio.h>
2. #include <string.h>
3. #include <stdlib.h>
4. #include <crypt.h>
5. #include <time.h>
7. int n\_passwords = 4;
9. char \*encrypted\_passwords[] = {
10. "$6$KB$6S9dCIrK1jRJu0AoISAn1nWkUEnmDAGm/sKs1Vb1GJXhSrRJv0pe9jyRvM9ohg96sSQt9IPNPC6obgGTl6P2A1",
11. "$6$KB$e1fG/f7Dr56YtgibdvLg7KpRb2bpCgGLv4eywNCmXXEgSV6jInDFCSkUoBq6Cn67b1GscDjxXExe9H3gudFgc.",
12. "$6$KB$mSVXI9v7J/9czxiCGGERm7BRZgkHaPo1TNZ8AqVdnkfz4INPofJQbRlGMpVzfFvFNIS5i6T5JLocC87tlG/NO/",
13. "$6$KB$FsCnEgeVl5KRBe62eF4R3mxZORQHEVeBzPXartqdZsZ3rfvLHgfQhEZtQM5xEFuqrPLN5h2/0DCy1F41oRFGv0"
14. };
16. /\*\*
17. Required by lack of standard function in C.
18. \*/
20. void substr(char \*dest, char \*src, int start, int length){
21. memcpy(dest, src + start, length);
22. \*(dest + length) = '\0';
23. }
25. /\*\*
26. This function can crack the kind of password explained above. All combinations
27. that are tried are displayed and when the password is found, #, is put at the
28. start of the line. Note that one of the most time consuming operations that
29. it performs is the output of intermediate results, so performance experiments
30. for this kind of program should not include this. i.e. comment out the printfs.
31. \*/
33. void Passwordcrack(char \*salt\_and\_encrypted){
34. int x, y, z, a; // Loop counters
35. char salt[7]; // String used in hashing the password. Need space for \0
36. char plain[7]; // The combination of letters currently being checked
37. char \*enc; // Pointer to the encrypted password
38. int count = 0; // The number of combinations explored so far
40. substr(salt, salt\_and\_encrypted, 0, 6);
42. for(x='A'; x<='Z'; x++){
43. for(y='A'; y<='Z'; y++){
44. for(z='A'; z<='Z'; z++){
45. for(a=0; a<=99; a++){
46. sprintf(plain, "%c%c%c%02d", x, y, z,a);
47. enc = (char \*) crypt(plain, salt);
48. count++;
49. if(strcmp(salt\_and\_encrypted, enc) == 0){
50. printf("#%-8d%s %s\n", count, plain, enc);
51. } /\*else {
52. printf(" %-8d%s %s\n", count, plain, enc);
53. }\*/
54. }
55. }
56. }
57. }
58. printf("%d solutions explored\n", count);
59. }
61. //Calculating time
63. int time\_difference(struct timespec \*start, struct timespec \*finish, long long int \*difference)
64. {
65. long long int ds = finish->tv\_sec - start->tv\_sec;
66. long long int dn = finish->tv\_nsec - start->tv\_nsec;
68. if(dn < 0 ) {
69. ds--;
70. dn += 1000000000;
71. }
72. \*difference = ds \* 1000000000 + dn;
73. return !(\*difference > 0);
74. }
75. int main(int argc, char \*argv[])
76. {
77. int i;
78. struct timespec start, finish;
79. long long int time\_elapsed;
81. clock\_gettime(CLOCK\_MONOTONIC, &start);
83. for(i=0;i<n\_passwords;i<i++)
84. {
85. Passwordcrack(encrypted\_passwords[i]);
86. }
87. clock\_gettime(CLOCK\_MONOTONIC, &finish);
88. time\_difference(&start, &finish, &time\_elapsed);
89. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
90. (time\_elapsed/1.0e9));
91. return 0;

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

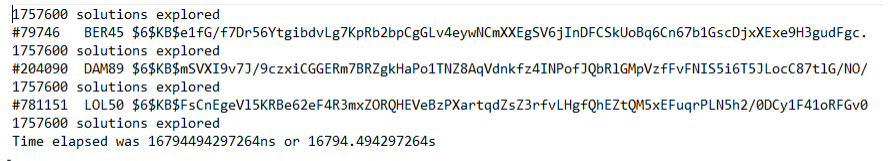


Figure 2 Three initial password cracking

In my hypothesis I said that it will take about 17,628 second to complete 3 initial program but it took about 16794.49 second.

Estimated time=17,628 second. (4.89 hrs)  
Time difference = 17,628 -16,794.49 =834 second (13.9 min)

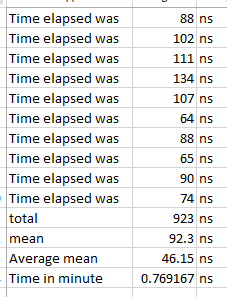
Write a paragraph that compares the original results with those of your multithread password cracker.

We executed simple program and multithread program for 10 times and calculated mean running time.

A picture containing crossword puzzle

Description automatically generated

Mean running time of simple program is 678425696637.6 second.



Mean running of multithreading program is 92.3 nano second.

In this program we created two threads (kernel\_function\_1 and kernel\_function\_2) to work on the program where the first thread cracks the password from the letter A to M and the second thread cracks the password from letter N to Z. Both thread will run Simultaneous explore the possible password. Which results to the mean time of this program was used was reduced to half which was proved by comparing above tables.

1. #include <stdio.h>
2. #include <string.h>
3. #include <stdlib.h>
4. #include <crypt.h>
5. #include <time.h>
6. #include <pthread.h>
8. int n\_passwords = 4;
10. char \*encrypted\_passwords[] = {
11. "$6$KB$0G24VuNaA9ApVG4z8LkI/OOr9a54nBfzgQjbebhqBZxMHNg0HiYYf1Lx/HcGg6q1nnOSArPtZYbGy7yc5V.wP/",
12. "$6$KB$VDUCASt5S88l82JzexhKDQLeUJ5zfxr16VhlVwNOs0YLiLYDciLDmN3QYAE80UIzfryYmpR.NFmbZvAGNoaHW.",
13. "$6$KB$0n1YjoLnJBuAdeBsYFW3fpZzMPP8xycQbEj35GvoerMnEkWIAKnbUBAb70awv5tfHylWkVzcwzHUNy/7l7I1c/",
14. "$6$KB$HKffNNiGzngqYueF89z3gwWZMg.xUBIz/00QSCbgwKtRHmwUbZX6jTH4VUAg3L3skaO8qtNf5LE7WP39jQ7ZJ0"
15. };

18. void substr(char \*dest, char \*src, int start, int length){
19. memcpy(dest, src + start, length);
20. \*(dest + length) = '\0';
21. }
23. /\*\*
24. This function can crack the kind of password explained above. All
25. combinations
26. that are tried are displayed and when the password is found, #, is put
27. at the
28. start of the line. Note that one of the most time consuming operations
29. that
30. it performs is the output of intermediate results, so performance
31. experiments
32. for this kind of program should not include this. i.e. comment out the
33. printfs.
34. \*/
36. void posix()
37. {
38. int i;
39. pthread\_t thread1, thread2;
41. void \*kernel\_function\_1();
42. void \*kernel\_function\_2();
43. for(i=0;i<n\_passwords;i<i++) {

46. pthread\_create(&thread1, NULL,kernel\_function\_1, encrypted\_passwords[i]);
47. pthread\_create(&thread2, NULL,kernel\_function\_2, encrypted\_passwords[i]);
49. pthread\_join(thread1, NULL);
50. pthread\_join(thread2, NULL);
51. pthread\_exit(&thread1);
52. pthread\_exit(&thread2);
54. }
55. }
57. void \*kernel\_function\_1(char \*salt\_and\_encrypted){
58. int x, y, z; // Loop counters
59. char salt[7];
60. char plain[7]; // The combination of letters currently being checked
61. char \*enc; // Pointer to the encrypted password
62. int count = 0; // The number of combinations explored so far
64. substr(salt, salt\_and\_encrypted, 0, 6);
66. for(x='A'; x<='M'; x++){
67. for(y='A'; y<='Z'; y++){
68. for(z=0; z<=99; z++){
69. sprintf(plain, "%c%c%02d", x, y, z);
70. enc = (char \*) crypt(plain, salt);
71. count++;
72. if(strcmp(salt\_and\_encrypted, enc) == 0){
73. printf("#%-8d%s %s\n", count, plain, enc);
74. }
75. }
76. }
77. }
78. printf("%d solutions explored\n", count);
79. }
81. void \*kernel\_function\_2(char \*salt\_and\_encrypted){
82. int i, j, k; // Loop counters
83. char salt[7]; // String used in hahttps://www.youtube.com/watch?v=L8yJjIGleMwshing the password. Need space
84. char plain[7]; // The combination of letters currently being checked
85. char \*enc; // Pointer to the encrypted password
86. int count = 0; // The number of combinations explored so far
88. substr(salt, salt\_and\_encrypted, 0, 6);
90. for(i='N'; i<='Z'; i++){
91. for(j='A'; j<='Z'; j++){
92. for(k=0; k<=99; k++){
93. sprintf(plain, "%c%c%02d", i,j,k);
94. enc = (char \*) crypt(plain, salt);
95. count++;
96. if(strcmp(salt\_and\_encrypted, enc) == 0){
97. printf("#%-8d%s %s\n", count, plain, enc);
98. }
99. }
100. }
101. }
102. printf("%d solutions explored\n", count);
103. }
105. //Calculating time
107. int time\_difference(struct timespec \*start, struct timespec \*finish, long long int \*difference)
108. {
109. long long int ds = finish->tv\_sec - start->tv\_sec;
110. long long int dn = finish->tv\_nsec - start->tv\_nsec;
112. if(dn < 0 ) {
113. ds--;
114. dn += 1000000000;
115. }
116. \*difference = ds \* 1000000000 + dn;
117. return !(\*difference > 0);
118. }
119. int main(int argc, char \*argv[])
120. {
122. struct timespec start, finish;
123. long long int time\_elapsed;
125. clock\_gettime(CLOCK\_MONOTONIC, &start);
126. posix();
128. clock\_gettime(CLOCK\_MONOTONIC, &finish);
129. time\_difference(&start, &finish, &time\_elapsed);
130. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
131. (time\_elapsed/1.0e9));
132. return 0;
133. }

Functions Explanation

Posix() : In this function two thread function, \*kernel Function\_1 and Kernel Function\_2 is created by using Pthread\_create(). While creating Thread 4 parameter is passed that is &thread1 (location of newly created thread), NULL (attribute), kernel\_function\_1 (it is the main function for the thread) and encrypted\_passwords ( it is the argument passed to the start or main function). After that two thread is joined by Pthread\_join()

Kernel Function\_1() and Kernel Function\_2()

\*Kernel function\_1 and \*Kernel Function\_2 is used in the program above. salt\_and\_encrypted is send inside this function as a parameter. They are the main function for the thread; the thread begins executing user code at this address. The password to check form AA00 to MZ99 is written in kernel function\_1 whereas the password to check form NA00 to ZZ99 is written kernel function\_2. Using the crypt function a unique code is generated and then checked with our password. This function can crack the kind of password explained above. All combinations that are tried are displayed and when the password is found, #, is put at the start of the line.

time\_difference ()

The function is used to generate the total time taken by the program to run. The time starts only after the clock\_gettime(CLOCK\_MONOTONIC, &start); function is called. In the finish variable the address of the finished time is stored. The final time is printed after the time is calculated.

Crypt ()

It has two parameters plain and salt. This function adds the salt to the plain password and match with the given password.

## Image Processing

Insert the image displayed by your program



1. #include <stdio.h>
2. #include <stdlib.h>
3. #include <time.h>
4. #include <GL/glut.h>
5. #include <GL/gl.h>
6. #include <malloc.h>
7. #include <signal.h>
8. #include <pthread.h>
10. /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*
11. Displays two grey scale images. On the left is an image that has come from an
12. image processing pipeline, just after colour thresholding. On the right is
13. the result of applying an edge detection convolution operator to the left
14. image. This program performs that convolution.
16. Things to note:
17. - A single unsigned char stores a pixel intensity value. 0 is black, 256 is
18. white.
19. - The colour mode used is GL\_LUMINANCE. This uses a single number to
20. represent a pixel's intensity. In this case we want 256 shades of grey,
21. which is best stored in eight bits, so GL\_UNSIGNED\_BYTE is specified as
22. the pixel data type.
23. \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/


27. #define width 100
28. #define height 72
29. typedef struct arg\_t{
30. int start;
31. int stride;
32. }arg\_t;
34. unsigned char image[], results[width \* height];
36. void edges(unsigned char \*in, unsigned char \*out,arg\_t \*args) {
37. int i;
38. int n\_pixels = width \* height;
40. for(i=args->start;i<n\_pixels;i+=args->stride) {
41. int x, y; // the pixel of interest
42. int b, d, f, h; // the pixels adjacent to x,y used for the calculation
43. int r; // the result of calculate
45. y = i / width;
46. x = i - (width \* y);
48. if (x == 0 || y == 0 || x == width - 1 || y == height - 1) {
49. results[i] = 0;
50. } else {
51. b = i + width;
52. d = i - 1;
53. f = i + 1;
54. h = i - width;
56. r = (in[i] \* 4) + (in[b] \* -1) + (in[d] \* -1) + (in[f] \* -1)
57. + (in[h] \* -1);
59. if (r > 0) { // if the result is positive this is an edge pixel
60. out[i] = 255;
61. } else {
62. out[i] = 0;
63. }
64. }
65. }
66. }
68. void \*Detection(void \*args)
69. {
70. edges(image,results,args);
71. }

74. void tidy\_and\_exit() {
75. exit(0);
76. }
78. void sigint\_callback(int signal\_number){
79. printf("\nInterrupt from keyboard\n");
80. tidy\_and\_exit();
81. }
83. static void show() {
84. glClear(GL\_COLOR\_BUFFER\_BIT);
85. glRasterPos4i(-1, -1, 0, 1);
86. glDrawPixels(width, height, GL\_LUMINANCE, GL\_UNSIGNED\_BYTE, image);
87. glRasterPos4i(0, -1, 0, 1);
88. glDrawPixels(width, height, GL\_LUMINANCE, GL\_UNSIGNED\_BYTE, results);
89. glFlush();
90. }
92. static void key\_pressed(unsigned char key, int x, int y) {
93. switch(key){
94. case 27: // escape
95. tidy\_and\_exit();
96. break;
97. default:
98. printf("\nPress escape to exit\n");
99. break;
100. }
101. }
102. int time\_difference(struct timespec \*start, struct timespec \*finish,
103. long long int \*difference) {
104. long long int ds = finish->tv\_sec - start->tv\_sec;
105. long long int dn = finish->tv\_nsec - start->tv\_nsec;
107. if(dn < 0 ) {
108. ds--;
109. dn += 1000000000;
110. }
111. \*difference = ds \* 1000000000 + dn;
112. return !(\*difference > 0);
113. }
114. int main(int argc, char \*\*argv) {
115. signal(SIGINT, sigint\_callback);
116. glutInit(&argc, argv);
117. struct timespec start, finish;
118. long long int time\_elapsed;
120. clock\_gettime(CLOCK\_MONOTONIC, &start);


124. clock\_gettime(CLOCK\_MONOTONIC, &finish);
125. time\_difference(&start, &finish, &time\_elapsed);
126. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
127. (time\_elapsed/1.0e9));
129. printf("image dimensions %dx%d\n", width, height);
130. pthread\_t t1, t2, t3, t4;
132. arg\_t t1\_arguments;
133. t1\_arguments.start = 0;
134. t1\_arguments.stride = 4;
136. arg\_t t2\_arguments;
137. t2\_arguments.start = 1;
138. t2\_arguments.stride = 4;
140. arg\_t t3\_arguments;
141. t3\_arguments.start = 2;
142. t3\_arguments.stride = 4;
144. arg\_t t4\_arguments;
145. t4\_arguments.start = 3;
146. t4\_arguments.stride = 4;
148. void \*Detection();
150. pthread\_create(&t1, NULL, Detection, &t1\_arguments);
151. pthread\_create(&t2, NULL, Detection, &t2\_arguments);
152. pthread\_create(&t3, NULL, Detection, &t3\_arguments);
153. pthread\_create(&t4, NULL, Detection, &t4\_arguments);
155. pthread\_join(t1, NULL);
156. pthread\_join(t2, NULL);
157. pthread\_join(t3, NULL);
158. pthread\_join(t4, NULL);


162. glutInitWindowSize(width \* 2,height);
163. glutInitDisplayMode(GLUT\_SINGLE | GLUT\_LUMINANCE);
165. glutCreateWindow("6CS005 Image Progessing Courework");
166. glutDisplayFunc(show);
167. glutKeyboardFunc(key\_pressed);
168. glClearColor(0.0, 1.0, 0.0, 1.0);
170. glutMainLoop();
172. tidy\_and\_exit();
173. pthread\_exit(&t1);
174. pthread\_exit(&t2);
175. pthread\_exit(&t3);
176. pthread\_exit(&t4);
178. return 0;
179. }
181. unsigned char image[] = {0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
182. 0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,
183. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
184. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
185. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
186. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
187. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
188. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
189. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,
190. 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,
192. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,
193. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
194. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
195. 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,
197. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
198. 0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
199. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
200. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
201. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
202. 0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
203. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
204. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
205. 255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,
206. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
207. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
208. 0,0,0,0,0,0,0,255,255,0,0,0,0,255,255,255,255,255,255,
209. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
210. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,
211. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
212. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
213. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,0,0,0,255,255,
214. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
215. 255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
216. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
217. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,0,0,
218. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,
219. 255,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
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417. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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459. 0,0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,
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531. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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542. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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547. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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557. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
558. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
559. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
560. };

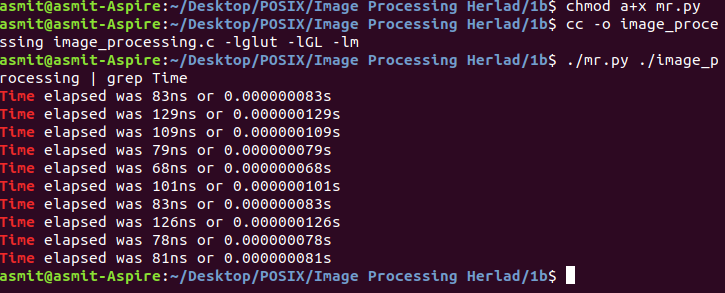
Code Explanation:

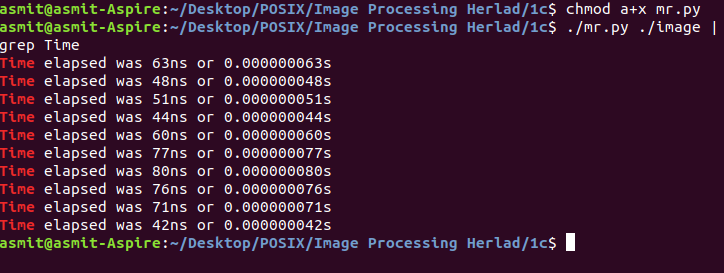
4 threads are used by the program to demonstrate 2 results of the single image. The image on the left presents the image after colour thresholding and the right image presents the image after using edge detection using convolution. In the program the black is represented as 0 and the white as 256. The final image is stored as pixel intensity value

edges ():

The array of the pixel intensity value is received by this function which includes the result to be sent and the structure that is created for the image. The number of pixels to be stored in the integer is stored. The convolution in each of the pixel in the loop is then started. If the edges are in the pixels then the value is set to 255 or the value or set to 0.

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.





![A screenshot of a cell phone

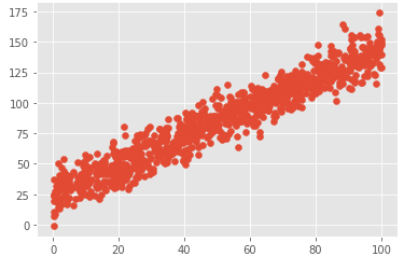
Description automatically 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yy+INctdVa3stD1WCxTTRBE0dwn7rzGdmXfuPmnbtZQNq8HJr0b7Zbf8/EX/fYrmLzwho15rM962q3MVtdXEV1d6dHNGLe5mj27HfKlx9xMhWCnYMg85F8V3/Wq/S4PYk8YalqEepaBoulXrafJq948ct5HGjyRRxxNIwQOGXcSoGSCACeM4rltJ8QeI/EHiBPCw16WylsWvzcanBbQGa5EMqRxDaytGuRJlsKMleNvNdTd+GNPvIjv1+/W6j1B9Qtbz7TG8tm7KVKR71ZRHtLLsZWGGPfBFY+CdIihtG0/Xb6wv7bz92pQTQmefzmDS796Mh3MFbhRtKjbtHFJef9O2n3Mb8v61f56HI6f4y8TeJtEv7621caZJouiR3kiwW8TJeXB80nfvDYjxDjCFT85+bgVZbxjr9/peqeKbbU2tbPTL61tk0sQRNHOjLCZS7MN+4+cdu1lA2rwcmuhuPAPh94Et7DVLrTbc2Kafcw2lxHi8t0JwkjOrNn5n+ZSrHeeemJ7jwZoc+qSXCanPb2c88Nzc6ZDLELa4liChHYFS4xsTIVgp2DIPOaXxXf9a/5dPkS9tP60/z6nNR+L9dgsbHxVcam0tjfavcWR0jyIhHHCplVCr7RJ5mYgSSxHzH5RgVSu/G3ibw54a0zXbzVBqb61o096tpLbxpFaThEeMRlArlBv2ncWJwDkV2dv4N0S31Vbn+1LiSziupbyHS5JojbQzybt7gBd5yXc7WYqC5wBxiva+APD0Vq1ne6lc6jYrZSWFraXc8fl2lvJgMkZRVY8KoDOWYBRg9cyvh1/rS1vv6lac1+n/B/yKB8Sav4T1y50fU9Tm8Q3E+nQz2CzQxRSSXLu0flDy1UbCQGyRlQGJYgcS+FrjxFrHhbUE1rxQ1rc6dqtzBc6hBawKfKj7LvUoozzuZWOBjryNG38E+HXMr+IbhPE8sixxiTWlgm8tI921VVUVRjexzjcd3JPGM2T4XeFV0i507S72TSILq/+3TixFsglwSVhdWjKtEpPCEEfWn3/rqrfh/Xee39dNfx/rtseCNR1HVvCWmXurymeWWeXyrhoxG1xCDIIpSoAALIFbgAc9B0o8PeL5te8Rajp32awtksZJI3he/P21drbVd7fyxtRvvK285BU9+NGwjFhBBDc63NqjiYsZ7ryVcDYRjESIuPwzz1qnbaFap4kj1q/wBfutSngSVLWK5a3VLZZCpYL5caMeFUfMW4HrzT+15B0OkoqH7Zbf8APxF/32KKQzIs/wDkYYP+vWb/ANDiqTRfFuh+IdEn1fSNQSext2dZpSjJ5ZQZbIYAjA56dOajtP8AkYIf+vSb/wBDirzHRvDOuQafpOiJp11Hp/iW1hTVS8JUWhgb95v7qZYdsYz3WjVu39fPyHpa7PW9D1zT/Eejw6po05ns59wjkaJoydrFT8rAMMEEcitCvFr3QdVOk6Gt/YA6TBeam1xa3mhzalGJXuGMLtaxsrsNhfa/zAbgccgiTUtJuI/CmjaTLpw1mwMV28U954au5kgYuPLt1szIGhwpISWRsKq4BAak3pdf1/X4+ugJa2f9f1/Wh7LRXkel+D/7eXTz4t0Wa9MXhC2iK3sDMq3Pz7gQePNGf95cnGM16H4PF2PBGiDUlmW8GnwCdZwRIH8sbtwPOc5zmrtv5f5tfp+JN9v66J/r+Bs0UUVIwooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigCGD/AF1z/wBdB/6AtTVDB/rrn/roP/QFqagAooooARmVELuwVVGSScACufsfHfh3UfPNtfsEht2ujJNbSxJLCv3pY2dQJUHHzIWHI55Gd24ijntpYp03xSIVdcZ3KRgjivLdD02a08R2l7pUviW90Tw/pE8Maahp4gkBbYEhgRoY3kIWPJZ9wyEAOSaXX+uz/wCAPoehaL4j03xB9oGmyT+Zasqzw3NrLbSx7hlSY5VVsEdDjBwcdDVHWfHWieH5Jxqw1SFLcgSzro93JCucY/erEUPUDIPXiuY8N3tzpGpeJtZNjr+s2kiWu27utNaG+uZBlGjWErGDGgKnIjX7z8sc43fEdrc694u0bRjazjS7Vv7TvbgxnypGjOIYd3Qnf85HYRr61XVf16/11J6M6a3OZbg/9NB/6AtTVyPj+wm1PwXqdnbQTzvLd2w2W+7ftEsJYjbyMAE5HTGa5vUvCVhp8virTLSxuNK0W4gsJYlsNLkuYZJld92YI1PmKdkYkUdV6kZzUjR6lRXCaZbatcfCPUrXQ9Lt9E1BobqKxjtLRrFXOWCSrC2GhLcHDHIJznvXK3ei2txpOpN4H8M6hpUDeGryC/hfTZbVrqdo18lCjKDNKCJPnG77xG47qJO1/Jfo2OKvbz/4H9fI9lorG8J6HY6D4btLbT7COyLxJJOqx7WklKgM7nqznHLNknvWzVyXK2iIu6uFFFFSUQwf665/66D/ANAWpqhg/wBdc/8AXQf+gLU1ABRRRQAVh6x4y0LQb77Jqd48cqxiWXy7aWVbeMnAeVkUrEpIPzOVHB54Nblea/EbR/tMuqRaFJryazrNgtm9vZWW+0uR86p50zwskYUO27Do23320nfoNJPc7/UtTtNJ0576+kZYE2gmONpGYsQqhVUFmJJAAAJJPFZieNNHl0oahb/2hcQ+e1uyQaXcyzRSL1WSJYy8ZH+0o6j1FV59Wex0m+05rbXI202K3ha/tLHzWk3qB5kKkP5mzqw2tj0Nc/4bu9S0Dwb4m1C10rUb+Vr+WawNzaPHd6i7qgDyxEAp+8JXIRAEQHaAMlvd21t/wP6/pijdpX3f+RuR/Enw1Kq+TNqMkjTyW4gTR7tpg8YUuDGIt4wHXJIxzXR2V5Ff2Ud1AsyRyLuUTwPC4HujgMv0IFeY6l4fuPDMnhCEXutQ/ZYLw3upaTpxu5Wnl8tmLL5MoAd9xyV7da7FbfWtU09DZ6vG2nTWbRlb/SpIbx3KFd7NvQId2DjyR3xjIwpaRbWtgjq1fqLY+P8AwzqLzi21PCwwSXBlmgkijkijOHkjd1CyIp6shYDI9RU1h4p0rxBb30Omy3AmggEkkN1ZzW0gRgdrBJVUlTtPzAY4Neataare+F9GsrTw1dzXPh/w9dWt7aXtrJFFLK0SRCFGO0TAlWbMZIIUfMCRW94Jt7qHVtZK/wBq31idOhRdT1qzlt7jeoYeQolClo1HzZ25y53M5ORdlzW/rr/wP6sK7tf+un+b/q56TRXnPjOwi/4Tyw1G30w61fKIIhZXmiS3EMa+bnzIbrb5du4DMzEk52JwMA16NUrVXG97BRRRQAUUUUAFQ3n/AB4z/wDXNv5VNUN5/wAeM/8A1zb+VAFCfxNpFt4otvDs94E1W6hM8NuUb50GckNjbn5TxnPB4pY/EelS+J5fD0d1u1SG3+0vAI3+WPIGd2NufmXjOeQcc1xPjbRtTuPGF1rGl2c8lxpem213ZskRYSyxTyM8KnoWaNmXHX5xWZDoHiRprjVLK1uLbW9Y0PUbkyFSnkXErw+TCWPCusaIuD/cJ9TST0T9fwvb77f1cbWrS8vxtf7r/wBWPXaK8a8P6RPpdrqF5olkftMOjSxSaXaeGrzSPtr4Xb5k7yMJJFO4BlO472IJqja6DfTaX4ptbPSJIbG7XTGij0/Q7jSo5HFwfNZImYuGChdzjacAHHQmra2X9ak30v8A10/zPc6K4/wtoEHh7xrr9tpOmLp2ky21pJEkMPlwtL+9WQrgYLYEe7HPTNdhSGFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAENn/x4wf9c1/lU1Q2f/HjB/1zX+VTUAFFFFAFe/v7XTLCa91CdLe2gQvLLIcKoHesebxxoVrokurX9xc2FpE+zN9YT27u23dhI5EDucAn5Qeh9DVP4l6ddan4Jkis4ribyru2uJobUt5skUc6O4Tb827apIxzkcc1zAnu7bwZ4yRYPEVxpd6Ht9HhvLW7ubos1vhvldWmWMuDgyYA56AjMtvlk+3/AAPzv+BSSbS7npttdw3dlFdwSBoJoxKjkEZUjIPPTj1rJ0jxjomu6gbHTrmZrjyftCLNaTQiaLIHmRtIqiRckfMhI5HqKo+G9fVND0Cy/svV90tr5UkkmnSxLbtFEpYSBwrDJ4UgEMelZHhfV/8AhJvG51rU9O1fTp44JLTTrO70i5iEMRYM8ksrRiPe5RcKGwAAMkk40kkptLbX9bGabcE3vod3Z/8AHjB/1zX+VTVw+v8Ah238QeKfCianpv2/TobW6M6yRl4dxWLYJB90gkEgNxkZxkVx99of2fwdpIutLnvLrTHv47PR77QJ9Qtpo/PbylIVcQttVAkjHAVjwQags9ooqK2LG0h8yEQNsXdECCIzj7uRwcdKlqno7ErVBRRRSGFFFFAENn/x4wf9c1/lU1Q2f/HjB/1zX+VTUAFFFFABRRRQAUUUUAFFFFAGQnifS5dcbSYHuZ7qN/LkaCymkhifG7a8yoY0bGOGYHkeopde8UaN4ZihfXL9LXz22xJtZ3fkDIVQWIBZcnGBkZIrzjQtL1bTPE1ra2kevR6kuv3U9/I7XH9ny2UjSuGG79wSQ6YC/PuBzjBrZ8f602sfDP8AcaNriXN/JGYrM6XNJMgjuELbxGrBOFJG4jI6ZoWyf9f1/kwfxNf11/4f0Oo1vxlofh64MOrXM0TKiySvHaTSpAjEgNK6KVjUkHlyBwfQ0248Z6Pb6xNpf/EwnuoGRZRaaXdXCRlwGXdJHGyjIIPJrmPGviIa3BD4ej07XItL1KDff6guiXjlYCcGBUWIssjAEHcBtU55OBVa1lay+IWr3LXfibTrO6ltJLeCz0N5YLlBAgIdjbOydNpG5COeh5oWr1B+R6FqurWWh6XPqOq3C29rAAXkIJ6nAAAySSSAAASSQBzWUvjvw+2mterdXBVbkWjW/wBhn+0ibG7Z9n2ebu2/Njb93npzWP4w0vxFNoiz3c9rqkdlqlpepbafp8kUvkxTBnGDK/mMF5AUKSV4BJAHNarb3t/rVzriafq9ppl5rEDx3sFhP9ttVhtSvnJBtLgM/wC7O5CCucoQQaS/r8P839w3/X4npen6xY67Z2l9pcxlgaZ0y0bRsrKHVlZWAZWBBBBAIrTrjvh9Dd2/hW0ivrSS3K30/lPPE0c1yhLkTyo5LLI+dzA4OT0HQZXhWwi0/wCI96bHTDeR3JuZZ9VvNEltbq3YupEZuZFAuEJLBQv3VReWABqvtW8iel/M9GooopDObsEux4gh8yeFj9llxthIx80ef4vpW9tuf+e0X/fo/wDxVZFn/wAjDB/16zf+hxVu0AQ7bn/ntF/36P8A8VRtuf8AntF/36P/AMVU1FAEO25/57Rf9+j/APFUbbn/AJ7Rf9+j/wDFVNRQBDtuf+e0X/fo/wDxVG25/wCe0X/fo/8AxVTUUAQ7bn/ntF/36P8A8VRtuf8AntF/36P/AMVU1FAEO25/57Rf9+j/APFUbbn/AJ7Rf9+j/wDFVNRQBDtuf+e0X/fo/wDxVG25/wCe0X/fo/8AxVTUUAQ7bn/ntF/36P8A8VRtuf8AntF/36P/AMVU1FAEO25/57Rf9+j/APFUbbn/AJ7Rf9+j/wDFVNRQBDtuf+e0X/fo/wDxVG25/wCe0X/fo/8AxVTUUAQ7bn/ntF/36P8A8VRtuf8AntF/36P/AMVU1FAEO25/57Rf9+j/APFUbbn/AJ7Rf9+j/wDFVNRQBDtuf+e0X/fo/wDxVG25/wCe0X/fo/8AxVTUUAVIVuPNnxLFnzBn92eflX/aqXbc/wDPaL/v0f8A4qiD/XXP/XQf+gLU1AEO25/57Rf9+j/8VRtuf+e0X/fo/wDxVTUUAQ7bn/ntF/36P/xVG25/57Rf9+j/APFVNRQBDtuf+e0X/fo//FUbbn/ntF/36P8A8VU1FAFSFbjzZ8SxZ8wZ/dnn5V/2ql23P/PaL/v0f/iqIP8AXXP/AF0H/oC1NQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBUhW482fEsWfMGf3Z5+Vf9qpdtz/z2i/79H/4qiD/XXP8A10H/AKAtTUAQ7bn/AJ7Rf9+j/wDFUbbn/ntF/wB+j/8AFVNRQBDtuf8AntF/36P/AMVRtuf+e0X/AH6P/wAVU1FAEO25/wCe0X/fo/8AxVG25/57Rf8Afo//ABVTUUAQ7bn/AJ7Rf9+j/wDFUbbn/ntF/wB+j/8AFVNRQBDtuf8AntF/36P/AMVUV0tx9jm3SxEeW2QIyO3+9Vuobz/jxn/65t/KgA23P/PaL/v0f/iqNtz/AM9ov+/R/wDiqmooAh23P/PaL/v0f/iqNtz/AM9ov+/R/wDiqmooAh23P/PaL/v0f/iqNtz/AM9ov+/R/wDiqmooAh23P/PaL/v0f/iqiuluPsc26WIjy2yBGR2/3qt1Def8eM//AFzb+VABtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBDtuf+e0X/AH6P/wAVRtuf+e0X/fo//FVNRQBUtVuPscO2WIDy1wDGT2/3ql23P/PaL/v0f/iqLP8A48YP+ua/yqagCHbc/wDPaL/v0f8A4qjbc/8APaL/AL9H/wCKqaigCHbc/wDPaL/v0f8A4qjbc/8APaL/AL9H/wCKqaigCHbc/wDPaL/v0f8A4qjbc/8APaL/AL9H/wCKqaigCparcfY4dssQHlrgGMnt/vVLtuf+e0X/AH6P/wAVRZ/8eMH/AFzX+VTUAQ7bn/ntF/36P/xVG25/57Rf9+j/APFVNRQBDtuf+e0X/fo//FUbbn/ntF/36P8A8VU1FAEO25/57Rf9+j/8VRtuf+e0X/fo/wDxVTUUAVLVbj7HDtliA8tcAxk9v96pdtz/AM9ov+/R/wDiqLP/AI8YP+ua/wAqmoAh23P/AD2i/wC/R/8AiqNtz/z2i/79H/4qpqKAIdtz/wA9ov8Av0f/AIqjbc/89ov+/R/+KqaigCHbc/8APaL/AL9H/wCKo23P/PaL/v0f/iqmooAh23P/AD2i/wC/R/8AiqNtz/z2i/79H/4qpqKAIdtz/wA9ov8Av0f/AIqjbc/89ov+/R/+KqaigCHbc/8APaL/AL9H/wCKo23P/PaL/v0f/iqmooAh23P/AD2i/wC/R/8AiqNtz/z2i/79H/4qpqKAKky3HmwZliz5hx+7PHyt/tVLtuf+e0X/AH6P/wAVRP8A662/66H/ANAapqAIdtz/AM9ov+/R/wDiqKmooA//2Q==)

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

Above table shows the mean running time of original and multithreading program of image processing. Comparing the table, we recognize that the program which used multithreading program take less time that of simple program. This is because the multithreading program improves the performance and concurrency. Mean running time of simple program is 9.3 second and for multithread program is 6.12 second.

## Linear Regression

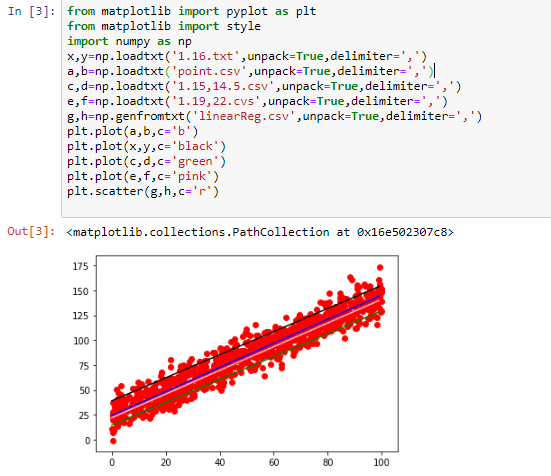
Insert a scatter plot of your data.



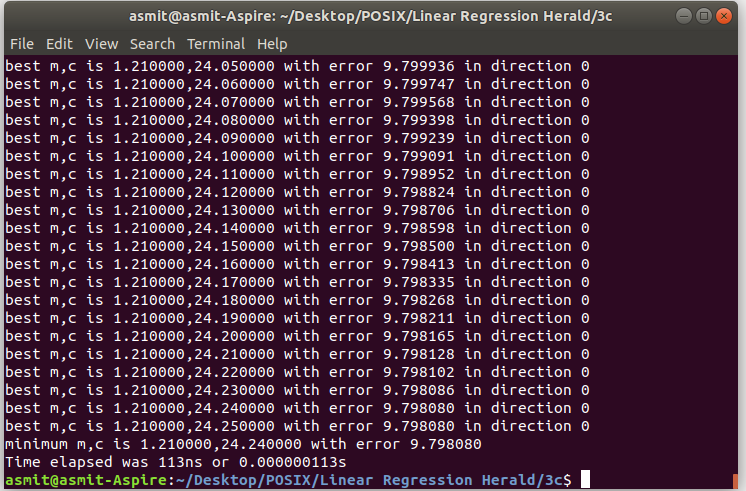
Have 3 guesses at the optimum values for m and c and present them in a graph that overlays your data.

Beside optimum value for m and c we have guessed the 3 other value for m and c which are shown in the figure below.

|  |  |
| --- | --- |
| Slope(m) | y-intercept ( c ) |
| 1.16 | 39 |
| 1.15 | 14.15 |
| 1.19 | 22 |
| 1.21 | 24.24 ( optimum) |



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



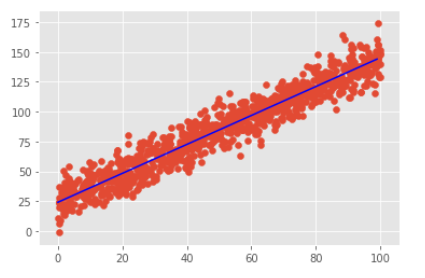


Figure 3 solution

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

1. #include <stdio.h>
2. #include <math.h>
3. #include <time.h>
4. #include <pthread.h>
5. #include <string.h>
6. #include <stdlib.h>
7. /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*
8. \* This program takes an initial estimate of m and c and finds the associated
9. \* rms error. It is then as a base to generate and evaluate 8 new estimates,
10. \* which are steps in different directions in m-c space. The best estimate is
11. \* then used as the base for another iteration of "generate and evaluate". This
12. \* continues until none of the new estimates are better than the base. This is
13. \* a gradient search for a minimum in mc-space
14. \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/
15. int i;
16. double bm = 1.3;
17. double bc = 10;
18. double be;
19. double dm[8];
20. double dc[8];
21. double e[8];
22. double step = 0.01;
23. double best\_error = 999999999;
24. int best\_error\_i;
25. int minimum\_found = 0;
27. double om[] = {0,1,1, 1, 0,-1,-1,-1};
28. double oc[] = {1,1,0,-1,-1,-1, 0, 1};
30. typedef struct point\_t {
31. double x;
32. double y;
33. } point\_t;
35. int n\_data = 1000;
36. point\_t data[];
38. double residual\_error(double x, double y, double m, double c) {
39. double e = (m \* x) + c - y;
40. return e \* e;
41. }
43. double rms\_error(double m, double c) {
44. int i;
45. double mean;
46. double error\_sum = 0;
48. for(i=0; i<n\_data; i++) {
49. error\_sum += residual\_error(data[i].x, data[i].y, m, c);
50. }
52. mean = error\_sum / n\_data;
54. return sqrt(mean);
55. }
57. int time\_difference(struct timespec \*start, struct timespec \*finish, long long int \*difference)
58. {
59. long long int ds = finish->tv\_sec - start->tv\_sec;
60. long long int dn = finish->tv\_nsec - start->tv\_nsec;
62. if(dn < 0 ) {
63. ds--;
64. dn += 1000000000;
65. }
66. \*difference = ds \* 1000000000 + dn;
67. return !(\*difference > 0);
68. }
70. void \*linear\_regression(void \*args){
71. int \*a=args;
72. int i=\*a;
74. printf("\n i in thread fun=%d",i);
75. dm[i] = bm + (om[i] \* step);
76. dc[i] = bc + (oc[i] \* step);
78. e[i] = rms\_error(dm[i], dc[i]);
79. if(e[i] < best\_error) {
80. best\_error = e[i];
81. best\_error\_i = i;
82. pthread\_exit(NULL);
84. }
85. }
87. int main() {
88. struct timespec start, finish;
89. long long int time\_elapsed;
91. clock\_gettime(CLOCK\_MONOTONIC, &start);
93. int i;
94. pthread\_t p\_threads[8];
96. be = rms\_error(bm, bc);
98. while(!minimum\_found) {
99. for(i=0;i<8;i++) {
100. pthread\_create(&p\_threads[i],NULL,linear\_regression,&i);
101. pthread\_join(p\_threads[i],NULL);
102. }
103. printf("best m,c is %lf,%lf with error %lf in direction %d\n",
104. dm[best\_error\_i], dc[best\_error\_i], best\_error, best\_error\_i);
105. if(best\_error < be) {
106. be = best\_error;
107. bm = dm[best\_error\_i];
108. bc = dc[best\_error\_i];
109. } else {
110. minimum\_found = 1;
111. }
112. }
113. printf("minimum m,c is %lf,%lf with error %lf\n", bm, bc, be);
115. clock\_gettime(CLOCK\_MONOTONIC, &finish);
116. time\_difference(&start, &finish, &time\_elapsed);
117. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
118. (time\_elapsed/1.0e9));
119. pthread\_exit(NULL);
120. return 0;
122. }
124. point\_t data[] = {
125. {72.12,100.78},{65.40,107.86},{82.27,131.60},{82.31,122.34},
126. {89.41,121.50},{71.37,113.51},{82.62,112.38},{69.57,102.96},
127. {65.38,99.27},{84.50,138.85},{87.18,114.17},{73.03,109.21},
128. {67.26,102.06},{72.25,113.23},{61.28,101.59},{41.60,84.24},
129. {40.14,57.03},{15.24,45.58},{61.88,89.90},{34.89,72.77},
130. { 8.91,36.34},{30.45,46.18},{67.93,89.35},{68.82,112.80},
131. {63.96,99.32},{32.36,56.12},{42.20,63.66},{24.47,60.75},
132. { 1.96,28.62},{41.42,68.41},{34.49,73.14},{ 8.03,22.13},
133. {80.55,117.79},{85.54,130.80},{68.99,103.13},{99.32,144.79},
134. {91.71,153.61},{71.17,108.40},{85.28,120.11},{99.52,128.68},
135. {13.24,31.67},{ 5.19,40.15},{ 9.84,57.36},{29.42,54.01},
136. {89.68,126.25},{29.45,41.30},{79.63,132.59},{71.88,107.31},
137. {20.05,48.38},{40.98,54.11},{56.55,63.61},{77.22,114.17},
138. {63.86,88.10},{92.93,134.84},{56.84,101.20},{34.31,71.18},
139. {93.89,116.43},{38.02,63.78},{61.25,94.71},{71.02,103.42},
140. {95.05,142.82},{96.24,133.50},{19.50,50.92},{41.14,70.59},
141. {91.49,134.05},{54.05,98.31},{36.59,68.48},{91.14,130.45},
142. {44.76,88.98},{77.28,138.16},{64.80,96.33},{43.25,70.08},
143. {55.55,95.70},{ 3.77,39.03},{ 3.23,44.69},{86.72,127.42},
144. {84.62,131.54},{26.13,71.24},{61.22,98.22},{53.90,96.07},
145. {64.81,109.35},{91.66,116.79},{53.65,104.81},{38.42,66.16},
146. {62.33,112.41},{ 7.41,29.86},{41.59,57.59},{56.49,91.60},
147. {15.94,42.82},{97.46,140.29},{57.17,85.11},{26.94,45.86},
148. {73.14,96.37},{18.61,60.58},{15.69,44.16},{20.79,33.86},
149. {65.02,106.03},{38.09,72.71},{87.15,116.68},{77.45,123.08},
150. {90.47,126.33},{26.80,44.96},{75.94,119.76},{33.83,69.11},
151. {63.59,103.98},{38.05,72.36},{68.28,110.76},{ 3.34,54.22},
152. {45.40,92.84},{78.37,113.49},{27.11,46.46},{32.32,68.44},
153. {20.97,30.90},{37.92,75.11},{96.85,130.96},{69.40,95.17},
154. { 3.29,30.06},{64.41,103.44},{15.80,52.64},{61.76,97.79},
155. { 1.62,33.98},{29.03,58.02},{18.74,34.93},{25.41,73.73},
156. {28.78,65.94},{14.64,50.31},{82.85,133.70},{41.62,90.32},
157. {99.28,144.95},{90.16,133.18},{40.45,77.72},{ 1.79,50.44},
158. {31.80,62.71},{26.30,40.89},{47.57,83.15},{17.78,44.90},
159. {69.48,93.13},{87.98,126.95},{69.84,106.00},{37.06,61.61},
160. {90.65,133.97},{10.73,46.60},{38.84,79.90},{ 4.75,33.89},
161. {48.99,89.31},{ 2.51,47.09},{34.99,86.40},{29.79,54.52},
162. {91.30,133.72},{74.12,122.86},{90.93,141.88},{51.14,89.93},
163. {84.53,142.49},{26.84,58.79},{ 6.95,20.98},{49.80,85.14},
164. {22.82,57.02},{44.08,89.32},{22.28,48.72},{21.12,50.68},
165. {65.69,93.93},{27.84,39.97},{ 1.92,40.39},{ 9.36,33.54},
166. {88.10,123.02},{18.15,63.84},{21.80,39.76},{64.42,101.03},
167. { 2.23,22.52},{55.68,99.56},{37.55,87.77},{74.23,104.87},
168. {11.96,37.30},{23.60,45.84},{11.13,34.32},{ 9.05,48.79},
169. {56.11,100.21},{19.31,54.44},{ 6.27,16.17},{64.65,101.39},
170. {50.25,77.59},{69.33,95.12},{47.52,87.79},{28.97,65.98},
171. {71.56,95.30},{19.71,41.47},{57.66,96.65},{41.07,74.10},
172. {35.08,79.46},{40.80,87.01},{ 0.31,19.82},{90.78,111.55},
173. {34.39,72.03},{99.97,139.40},{30.86,73.03},{14.37,50.15},
174. { 6.11,42.76},{21.75,80.30},{89.94,127.56},{10.86,42.40},
175. {13.07,42.98},{84.47,147.14},{83.44,132.18},{32.24,63.57},
176. {66.93,102.41},{34.48,68.96},{ 3.46,22.82},{94.84,130.83},
177. {49.41,107.26},{71.64,99.82},{47.28,80.62},{39.17,68.77},
178. {58.05,108.35},{69.27,109.81},{47.64,73.34},{34.64,73.15},
179. {22.86,46.34},{37.76,66.19},{ 3.12,39.11},{60.59,111.05},
180. {91.99,122.76},{96.60,138.86},{ 3.58,23.35},{22.81,60.18},
181. {13.93,21.32},{69.51,106.41},{19.57,43.39},{79.11,115.68},
182. {80.89,124.36},{44.42,57.78},{33.28,73.04},{21.45,49.88},
183. {70.57,113.77},{45.63,65.60},{55.99,72.21},{21.62,41.47},
184. {61.74,98.99},{ 9.30,29.77},{75.32,106.74},{27.97,73.44},
185. {74.77,115.98},{42.93,82.67},{92.32,138.05},{25.55,64.34},
186. { 0.48,23.51},{79.52,111.52},{52.83,70.58},{51.45,87.28},
187. {62.72,90.41},{ 4.16,40.60},{70.13,115.25},{55.96,97.34},
188. {93.88,154.09},{46.21,90.04},{34.75,51.46},{54.45,89.56},
189. {80.69,129.36},{45.14,73.00},{47.34,85.69},{70.16,118.02},
190. { 4.26,17.14},{61.56,98.04},{15.95,28.56},{74.06,118.48},
191. {65.29,99.71},{19.08,55.64},{37.82,72.36},{58.22,103.93},
192. {50.52,82.15},{26.25,60.91},{97.77,123.91},{39.13,68.03},
193. {15.09,41.88},{32.61,61.64},{11.23,22.85},{61.92,98.02},
194. {73.63,126.32},{35.12,54.74},{12.98,42.69},{83.87,128.60},
195. {45.65,78.81},{42.85,90.57},{76.74,117.53},{19.05,49.60},
196. {69.03,104.16},{23.66,54.97},{52.85,85.94},{82.07,128.27},
197. {74.77,111.22},{95.04,136.69},{40.49,49.53},{ 4.16,28.40},
198. { 7.69,51.29},{29.37,80.82},{86.06,122.19},{ 3.92,23.24},
199. {62.76,108.89},{27.12,54.24},{10.24,33.84},{79.86,107.97},
200. {57.09,85.27},{10.29,54.38},{53.50,82.98},{12.83,50.29},
201. { 2.09,13.69},{88.73,135.16},{42.72,87.10},{40.20,91.88},
202. {40.10,76.49},{80.22,133.65},{57.55,93.99},{29.34,69.08},
203. { 2.90,41.26},{44.60,82.03},{47.93,89.05},{98.17,123.11},
204. {17.21,45.91},{42.37,79.83},{90.89,119.42},{ 7.81,36.64},
205. {76.14,123.86},{47.79,83.40},{95.27,144.30},{44.13,98.20},
206. {19.97,37.36},{90.66,131.96},{75.41,117.80},{57.14,107.91},
207. {25.92,41.69},{90.86,130.36},{44.78,79.02},{23.00,29.10},
208. {91.67,118.13},{26.55,51.18},{41.60,74.91},{ 0.39, 6.79},
209. {86.31,102.08},{20.43,37.80},{ 5.39,28.65},{12.63,24.33},
210. {22.60,42.79},{ 1.77,14.54},{74.10,113.64},{54.46,87.67},
211. {18.64,49.32},{93.97,116.30},{42.62,87.04},{13.37,30.16},
212. {74.50,104.62},{18.28,67.85},{76.98,107.84},{25.89,57.35},
213. {13.52,42.87},{61.26,97.78},{ 5.97,31.34},{91.99,137.43},
214. {20.38,58.23},{ 9.59,31.56},{79.41,126.40},{89.90,134.36},
215. {73.18,111.44},{61.51,111.41},{99.96,147.82},{72.55,113.52},
216. {66.21,110.93},{36.47,59.41},{65.58,93.39},{24.93,51.71},
217. {58.00,95.89},{49.83,83.52},{53.35,89.98},{83.97,129.85},
218. {57.33,106.86},{53.94,98.13},{98.02,144.26},{47.28,72.52},
219. {45.48,100.70},{80.69,147.66},{96.14,140.01},{82.69,120.80},
220. {79.73,136.89},{11.42,27.51},{88.91,138.59},{25.53,51.26},
221. { 2.49,37.14},{63.89,93.28},{90.96,138.02},{15.27,53.03},
222. {25.39,51.31},{31.77,55.54},{88.25,124.46},{67.66,108.26},
223. {90.23,112.02},{17.40,43.85},{78.38,137.07},{96.28,149.45},
224. {77.38,120.54},{56.49,107.27},{99.00,141.67},{36.35,58.18},
225. {97.41,132.64},{15.03,48.28},{42.48,81.20},{62.95,105.32},
226. {99.76,147.11},{85.18,140.95},{99.23,131.84},{21.09,44.44},
227. {45.12,75.22},{80.36,119.71},{61.37,84.74},{82.64,128.58},
228. {70.34,108.16},{83.63,116.26},{47.73,67.57},{17.56,48.42},
229. {23.26,42.12},{41.81,82.17},{18.48,33.63},{39.11,70.14},
230. {84.20,123.97},{67.20,113.97},{52.74,87.79},{81.66,131.54},
231. {45.90,93.69},{20.82,34.77},{86.35,122.38},{78.93,106.82},
232. {10.56,44.66},{51.20,104.61},{93.79,131.97},{15.71,43.06},
233. {99.16,156.47},{90.70,135.27},{41.85,77.91},{73.41,106.66},
234. {57.51,108.55},{53.06,115.27},{25.72,67.45},{ 8.03,27.74},
235. {57.91,101.56},{35.87,57.47},{98.33,145.81},{50.96,76.84},
236. {57.86,102.10},{17.21,44.21},{95.62,154.59},{76.92,114.77},
237. {25.32,60.66},{43.60,68.34},{42.68,73.98},{60.36,84.81},
238. { 9.06,42.91},{ 4.16,18.44},{54.14,97.87},{ 4.87,35.92},
239. {75.38,112.62},{41.37,68.92},{88.16,163.96},{16.79,41.87},
240. { 9.77,40.62},{69.66,125.12},{70.35,118.66},{71.99,97.87},
241. {63.66,111.29},{ 2.01,19.46},{64.63,122.89},{48.39,84.19},
242. {28.15,64.69},{46.17,83.91},{25.12,45.94},{82.23,118.70},
243. {57.69,95.98},{24.42,62.91},{15.81,35.58},{75.28,106.87},
244. {95.74,133.25},{67.78,107.42},{80.89,128.72},{10.39,38.37},
245. {15.31,35.73},{61.45,110.46},{11.15,44.99},{30.80,63.26},
246. {84.29,122.39},{29.17,47.34},{80.68,138.44},{81.17,117.86},
247. { 8.47,32.78},{41.26,74.09},{43.50,71.18},{34.48,68.61},
248. {30.63,68.05},{88.63,137.28},{71.56,116.97},{21.03,39.12},
249. {88.20,116.24},{ 8.52,30.24},{95.79,137.27},{78.66,104.62},
250. {72.44,94.21},{71.60,106.34},{72.11,114.18},{34.50,59.18},
251. {22.85,60.95},{18.43,40.91},{69.24,119.69},{91.84,142.06},
252. {34.41,69.95},{95.06,136.92},{67.93,100.93},{46.96,71.82},
253. {63.92,102.14},{ 1.62,29.66},{95.24,133.60},{43.10,80.88},
254. {21.83,73.25},{35.01,62.42},{20.05,55.19},{18.64,45.92},
255. {40.28,75.26},{34.54,63.38},{84.74,117.68},{90.38,144.87},
256. { 9.91,24.87},{62.97,102.14},{34.40,79.20},{67.34,89.48},
257. {48.53,85.13},{24.57,51.59},{81.95,117.78},{22.23,49.77},
258. {75.86,125.20},{60.45,99.78},{19.93,35.57},{48.62,78.46},
259. {88.49,120.71},{13.33,40.67},{52.03,93.38},{38.43,80.28},
260. { 2.56,17.00},{18.39,58.10},{58.81,88.08},{75.76,96.69},
261. {69.78,98.83},{96.47,146.81},{47.32,79.89},{21.90,46.54},
262. {52.39,83.38},{75.49,107.96},{50.14,80.51},{41.54,73.80},
263. {76.07,117.48},{27.00,73.59},{81.59,122.88},{21.74,39.55},
264. {60.05,105.04},{75.68,102.72},{40.41,79.01},{ 0.32,24.82},
265. {50.06,106.14},{98.69,139.50},{64.17,109.26},{42.74,78.53},
266. {39.52,71.78},{55.14,97.37},{25.19,39.08},{99.31,142.63},
267. {67.50,91.86},{90.92,152.17},{81.99,129.38},{77.28,124.08},
268. {29.38,69.15},{ 3.81,41.93},{ 9.72,41.83},{25.75,53.09},
269. {57.28,85.11},{69.50,116.90},{20.00,51.46},{63.00,72.32},
270. {67.06,102.20},{37.85,64.86},{81.40,114.28},{13.32,58.41},
271. {67.21,103.77},{63.73,109.66},{91.43,141.66},{54.83,88.07},
272. {68.03,112.67},{ 0.51,27.76},{ 2.17,38.05},{36.26,66.58},
273. {72.67,116.52},{98.28,136.37},{85.27,128.64},{90.26,136.47},
274. {60.31,95.24},{32.77,58.94},{ 3.52,24.75},{15.98,45.49},
275. {94.25,145.90},{ 8.13,29.89},{61.13,81.38},{44.14,77.64},
276. {63.53,100.35},{49.35,97.92},{ 4.98,32.12},{25.53,57.45},
277. { 8.63,41.62},{24.23,56.27},{93.30,137.92},{43.72,71.72},
278. {54.15,89.12},{ 3.42,36.34},{57.75,85.68},{51.90,87.74},
279. {85.14,137.82},{99.27,173.87},{82.53,124.94},{15.38,44.42},
280. {66.66,108.56},{64.12,99.41},{39.08,73.77},{25.42,58.25},
281. { 1.29,36.39},{98.72,148.84},{70.09,112.06},{ 8.51,27.00},
282. {85.92,124.74},{88.32,127.04},{51.79,74.58},{36.46,62.45},
283. {49.29,85.33},{14.06,30.58},{24.83,34.82},{42.85,87.06},
284. {34.47,76.96},{59.16,90.44},{ 1.02,32.32},{61.80,108.22},
285. {72.52,95.83},{65.40,99.49},{53.32,93.79},{74.22,117.61},
286. {53.86,88.31},{39.84,80.11},{79.28,117.86},{34.57,76.73},
287. {21.69,55.55},{99.87,129.34},{72.12,108.86},{75.08,106.64},
288. {70.71,106.00},{18.35,67.45},{37.42,66.71},{ 0.70, 9.02},
289. {56.79,86.75},{74.04,100.45},{53.40,82.23},{42.13,70.45},
290. {82.43,123.55},{91.65,131.55},{94.99,153.70},{62.14,84.17},
291. {99.71,151.07},{33.24,73.77},{48.87,76.91},{68.57,118.95},
292. {14.28,46.22},{18.17,41.01},{95.93,133.32},{ 5.06,33.23},
293. {57.58,95.47},{18.71,39.10},{90.19,136.73},{26.98,50.08},
294. {11.36,26.14},{62.70,98.59},{49.32,80.54},{99.97,149.27},
295. {83.40,132.00},{25.30,48.62},{79.25,117.83},{81.09,109.23},
296. {31.46,51.02},{14.26,32.26},{33.53,52.63},{ 9.42,47.16},
297. {67.40,109.90},{18.56,32.79},{34.51,75.14},{49.00,77.38},
298. {15.69,50.80},{23.09,40.32},{32.03,67.86},{13.60,40.35},
299. {19.21,60.16},{78.56,111.57},{80.72,131.02},{50.19,79.64},
300. {55.60,81.78},{ 6.37,43.37},{42.78,74.85},{60.48,113.67},
301. {44.44,89.27},{54.02,90.24},{73.51,101.74},{16.41,56.73},
302. {70.94,104.90},{32.03,66.91},{13.12,49.71},{50.16,85.64},
303. {41.31,68.88},{69.25,123.25},{24.97,69.28},{40.80,86.30},
304. {32.28,67.01},{90.77,142.80},{66.77,104.70},{24.06,56.12},
305. {49.16,89.52},{46.10,95.56},{51.79,94.01},{56.11,100.66},
306. {88.49,126.71},{ 1.28,21.35},{35.55,64.10},{18.79,29.74},
307. { 5.40,40.02},{92.32,129.89},{21.13,47.05},{ 5.14,32.16},
308. {60.89,104.41},{43.45,76.07},{98.91,160.53},{99.31,155.80},
309. {74.71,121.53},{62.33,98.98},{58.66,101.10},{51.51,93.03},
310. {51.69,90.42},{19.47,31.22},{85.75,108.87},{64.20,100.48},
311. {96.60,142.66},{67.99,102.48},{68.37,120.07},{29.81,44.77},
312. {96.55,142.74},{30.59,43.25},{73.94,108.44},{49.77,88.88},
313. {59.48,98.21},{41.21,61.86},{38.63,83.41},{86.98,140.40},
314. {93.34,134.69},{87.92,119.52},{40.93,61.87},{ 2.43,30.68},
315. {50.74,71.81},{37.13,52.43},{ 1.50,22.18},{99.06,143.48},
316. { 1.67,27.67},{ 0.18,10.50},{54.13,77.05},{46.19,88.91},
317. {91.13,144.49},{ 8.95,28.33},{85.69,122.61},{50.30,95.60},
318. {48.63,103.49},{67.99,100.19},{69.21,112.13},{11.26,34.99},
319. {25.78,58.73},{84.35,112.36},{46.80,79.68},{69.54,117.99},
320. {40.30,74.33},{79.97,118.95},{23.28,55.71},{32.62,78.92},
321. {21.86,37.01},{ 5.07,22.57},{94.41,146.15},{40.14,60.81},
322. {95.80,125.35},{91.34,131.68},{72.55,113.56},{40.13,71.59},
323. {98.06,145.27},{90.55,144.08},{71.26,121.81},{33.85,71.13},
324. {85.74,142.63},{57.93,91.78},{ 7.63,39.30},{83.72,128.26},
325. {10.89,46.78},{39.79,66.98},{98.84,146.32},{84.62,123.91},
326. {23.16,31.94},{86.36,134.79},{44.19,63.74},{ 0.39,24.19},
327. {64.22,96.97},{66.47,103.78},{ 1.73,17.52},{22.25,36.77},
328. {31.88,59.39},{15.60,30.03},{16.08,41.91},{83.11,129.19},
329. {72.61,122.52},{19.02,41.06},{56.90,87.53},{65.85,97.02},
330. {81.40,120.35},{64.90,104.44},{73.35,119.00},{ 8.49,40.31},
331. {31.20,65.32},{28.29,75.05},{72.51,120.90},{20.42,48.84},
332. {71.46,111.59},{33.98,50.46},{72.48,111.29},{75.56,113.00},
333. {58.65,95.16},{23.66,44.95},{95.08,139.46},{80.12,115.20},
334. {67.77,101.97},{56.06,99.08},{99.03,138.47},{48.26,74.79},
335. {25.95,39.30},{85.20,137.70},{69.31,104.19},{86.19,122.91},
336. {37.99,87.47},{72.06,116.90},{ 5.66,28.92},{27.77,52.05},
337. {31.89,60.32},{18.01,48.92},{37.21,65.49},{73.76,107.20},
338. { 0.32,-0.71},{93.75,133.48},{69.11,109.63},{11.01,55.84},
339. {43.48,73.99},{20.76,57.44},{75.50,105.00},{98.74,150.46},
340. {40.75,90.93},{61.67,103.30},{93.48,155.96},{35.52,61.62},
341. {32.30,78.52},{28.92,49.61},{60.97,87.11},{13.59,47.58},
342. { 9.43,26.07},{58.00,107.90},{99.86,151.90},{34.01,57.82},
343. {39.02,59.14},{33.64,74.99},{ 2.28,20.21},{55.00,90.93},
344. {55.77,85.94},{79.17,134.03},{63.16,106.70},{17.58,32.28},
345. {24.29,34.68},{83.91,132.35},{96.44,129.86},{61.95,93.66},
346. {14.86,25.10},{15.53,33.29},{15.69,42.47},{80.60,126.11},
347. {16.01,46.33},{26.54,74.55},{ 2.67,37.10},{74.63,96.98},
348. {38.06,59.99},{56.59,96.87},{78.88,120.95},{87.56,121.75},
349. {73.54,119.27},{16.84,44.09},{44.24,89.36},{76.02,123.64},
350. {98.41,115.45},{12.11,48.19},{30.70,60.41},{55.51,100.49},
351. { 0.26,37.11},{83.43,124.44},{49.92,111.30},{65.55,99.48},
352. {77.61,119.44},{62.44,95.52},{21.80,61.06},{20.99,60.54},
353. {93.10,129.45},{54.96,91.05},{10.22,48.48},{66.77,108.83},
354. {40.83,87.14},{13.54,35.77},{31.44,62.92},{79.69,110.30},
355. {67.07,100.59},{28.81,78.71},{52.95,97.30},{39.89,81.67},
356. {58.79,75.89},{34.35,51.29},{38.03,64.97},{87.87,130.19},
357. {39.73,52.43},{ 1.64,31.22},{91.15,147.58},{54.08,101.10},
358. {53.53,74.54},{54.24,104.47},{15.04,51.28},{79.06,114.59},
359. {93.83,138.37},{94.89,122.18},{52.63,86.22},{27.83,68.05},
360. {54.51,94.07},{23.83,58.00},{86.88,141.66},{10.42,31.81},
361. {55.43,84.31},{45.04,85.30},{95.69,121.78},{17.28,35.32},
362. { 3.17,33.76},{51.61,69.81},{27.37,64.13},{88.92,160.98},
363. {31.40,64.46},{33.35,59.91},{82.48,128.89},{50.46,98.13},
364. {78.73,113.68},{70.08,115.27},{98.65,142.28},{ 9.15,50.95},
365. {16.74,35.73},{32.92,72.02},{ 1.29,18.94},{75.79,123.45},
366. {32.94,59.92},{61.72,81.50},{42.39,91.90},{70.15,108.81},
367. { 2.90,29.10},{59.68,87.41},{69.85,108.66},{71.21,107.81},
368. {24.09,46.47},{44.51,76.59},{ 7.30,34.83},{58.93,99.24},
369. { 1.24,22.60},{84.27,132.21},{54.11,87.19},{39.18,75.93},
370. {90.81,155.72},{67.68,88.19},{67.14,84.53},{53.98,86.47},
371. {67.28,106.68},{ 8.49,36.74},{34.96,62.55},{59.01,82.94},
372. {64.78,101.77},{66.24,110.82},{75.81,131.28},{62.82,76.02},
373. {73.95,116.37},{20.40,38.76},{45.06,84.65},{47.64,82.81},
374. {30.85,64.41},{77.10,112.67},{ 8.12,32.76},{39.56,53.41}
375. };

Code Explanation

This program used 8 threads to find the best slope, y intercept and minimum error form the given 1000 data set.

residual\_error()

This function is used to calculate the equation of the line and return the square if the e value. This function takes value of x ,y ,slope and y-intercept as a parameter.

rms\_error ()

This function calculates the square mean error of the 1000 sets of data where slope (m) and y-intercept(c) is passed as a parameter.

linear\_regression ()

The value of slope is calculated by comparing with 8 other values from different threads. rms\_error is used to calculate the best error.

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

![A screenshot of a cell phone

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDgRXhpZgAATU0AKgAAAAgABAE7AAIAAAAHAAAISodpAAQAAAABAAAIUpydAAEAAAAOAAAQyuocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAERpa2VzaAAAAAWQAwACAAAAFAAAEKCQBAACAAAAFAAAELSSkQACAAAAAzM2AACSkgACAAAAAzM2AADqHAAHAAAIDAAACJQAAAAAHOoAAAAIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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![A screenshot of a cell phone

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pDbQpFJuGDuQcHIGDkVXl8KeHJ0tkm8JadIlrGYrdXsoCIUOcqv90HJ4HHJp2oeNdB02O2ea7lnF1b/aohZWk10TDx+9IiRiqcj5jgUal420DSYoJbu9ZoZolmE9vbyzxpGxwsjvGrLGh5wzEA4ODwarW4uhoxQwwXM1xBpnlzzhRLKixhpAowu4g5OAcDPSp/Pk/59ZfzT/4qsLUfH3hvStUn0+9v5FuLZkFwEtJpFt9+NjSOqFUU7hhmIHXng46Ol5h5EPnyf8+sv5p/8VR58n/PrL+af/FVNRQBD58n/PrL+af/ABVHnyf8+sv5p/8AFVNRQBD58n/PrL+af/FUefJ/z6y/mn/xVTUUAQ+fJ/z6y/mn/wAVR58n/PrL+af/ABVTUUAQ+fJ/z6y/mn/xVHnyf8+sv5p/8VU1FAFS5mcxDNtKP3idSv8AeHvUvnyf8+sv5p/8VRdf6lf+ukf/AKGKmoAh8+T/AJ9ZfzT/AOKo8+T/AJ9ZfzT/AOKqaigCndxxX9nLaX2m/abaZSksMyxujqeoKk4I9jWPB4M8LWsM8Vt4N0uGO5Ty50jsLdVlXIO1gPvDIBwe4FM8X+JtW8M2V1qVtocN5plhb/aLqeW/8lyoJ3CJAjbmAGfmKA5ABPOG6t4rv9I1jT0uNHi/sq/vIrKK5N5i4Z5FyGWDZgqDwcuGADHbgci1f4A9Pz+40odF0m30gaVB4etYtODBhZpbwiEENuzsB253AHp15q1cwQ3jQNd6YJzbyiaEypG3lOAQHXJ4bBPI55Nc5qvijxLpWuabYSaBpUy6leG3t/J1eQy7ACzSshtgAFUZI3HnABORVHV/iDrHhrURD4h0HT1gSynvp30/VZLiSKKMcEo9vGDucqg+bqT6Gi/X+u4W6HU6hpGmatc21xqugW97PaNvt5bmCKRoWyDlCxJU5A6egqwIIRqBvhpgF20QhNxsj8woCSE3ZztyScdMmudsfFXiC6vbnSp/D9hbazHaxXkMDaqzQyROxU5kEO5XUqQRsI6YbnjKm+KFzpy6iut6Xpto9tfR6fBMurk20s7IZHDyvCnlrGoBY7W5OACeKNv6+X/ADf8Ar5/8E66PR9Li1qTWIvD9smpyLte+W3hEzjAGDJncRgAdewq15UP203n9m/6UY/KM+2PeUznbuznGecdK5fVfH50nwNHrhtbHUru4Dm2tdL1Hz4ZwgZmYTeWPlVFYsdnGMcnFSa14t1rTfDI8Q2ukaXLposUu5Dc6pJFICVzsVVt3DHkAHIyT0FGyfkG/zNw6XpzaN/ZDaFAdMK7PsRgi8nbnONmduM84xTLXTrHRdNWz0fRodOthMriG1ijiTcWGTtU4yaq6v4mn0PwQuuajp6w3Plw+ZavcYjgkkZVw8u35UUt8z7eACcdqZoPiG4123v472yhtbjT79LaQ2tybiCQjY2UkKITjdtIKjDAinrdr+v61FfRM1JbKznS6WbR45FvABdB4oiJ8DA38/NwMc9qrx6Fo8WtNrEXhy0TVG+9fLbQic8bf9Z97px16VU1Hx94c0nVJ9Ovr6RLm1ZFuAlpNItvvxsaR1QqincMMxA688HF0eJtMfXn0eJrqa7jYJIYbKaSKJiu7a8yoY0O0g4ZgeR6iku6H6iaromk68YTrnh211I25JhN5bwzeWTjO3cTjOB09BVtYYVvWvF0zF00YiacLHvKAkhd2c4BJOOnJqjrXi3R9AuVt9RnnNw0TT+Ta2c1y6Rg4MjLEjFVzxubAqN/G2gDVrPTIr5rq7vYI7mBLS3luA8Lkqsu6NSAmRyxIAyMkZGReQPzNjz5P+fWX80/+Ko8+T/n1l/NP/iqmooAh8+T/AJ9ZfzT/AOKqK5mcxDNtKP3idSv94e9W6huv9Sv/AF0j/wDQxQAefJ/z6y/mn/xVQ3ccV/Zy2l9pv2m2mUpLDMsbo6nqCpOCPY1Znmjt7eSeZtscal3Y9gBkmuQ8O+ObvWNQ0uPUNFXT7XW7WS70yUXnmu6LtOJU2L5bFHVsKXHUEjFG+n9f1oG2poWvg/wxZJMll4O0y3WdQkyxWNugkUEMA2OoyAcHuAatPoWjya2usyeHLVtUX7t81tCZxxj/AFn3unHXpVDxf4m1bwzZXWpW2hw3mmWFv9oup5b/AMlyoJ3CJAjbmAGfmKA5ABPOG6t4rv8ASNY09LjR4v7Kv7yKyiuTeYuGeRchlg2YKg8HLhgAx24HItWgeiZpx6PpcWtSaxF4ftk1ORdr3y28ImcYAwZM7iMADr2FQx+HNCia+MXhexQ6iCL0raQD7UCSSJP7+ST1z1rJ034g2+seLZ9J099H8m3nlgkE+rBLxjHkOyWwQkoGBGSy5AJxjGYvDnxD/wCEqN1LosGlXcMdu80FrDrCNfOAcJ5kGzbEG9TJxkZGcgJarTt+A+vz/E29J8OaFoNw8+heGLHTZpF2PJZ2kELMuc4JXGRkdKt+TDaQuLTThbiW4E0nlqi73Lgljg8sfWsOz8ay293rVr4psLfTJdItYryR7W7NzE8Um/GGMaENmNht288YJzUvhTxRP4r0Ga8vNLbS57fUDayWzTeYylHXqcDB55Hb1NVu/wCv63J2/ry/yNBNC0eLW21mPw5apqjZ3Xy20InORg5k+90469K0vPk/59ZfzT/4qs8eJtMfXn0eJrqa7jYJIYbKaSKJiu7a8yoY0O0g4ZgeR6ital0H1IfPk/59ZfzT/wCKoqaigDlLvT5dXsfEOm2zIs15pggjaQkKGYTKCcAnGT6UqeGL1datrwyweXFoTaaw3NkyFkOen3flPPX2q1o1pGmrXqhpseRCeZ3J+9J3J9q2vssf96X/AL/P/jSsnfz/AMmv1Y7vTy/zT/RHmcHw01bTodIlg8q9ubfRbbTbqKPXLzTVVoQfnWSBSZAd5GHUYwCDyRR4l+HOvalo50jR3t7bTTpKWVvaHWbuKOxkAbecIv8ApKsCozLjG3ODkg+mfZY/70v/AH+f/Gj7LH/el/7/AD/41Td3f5/n/mJe7t/Vrf5HH6p4M1C903xjbxTWofXYo0tizthCsCxnf8vHIPTPFdqo2oAewqL7LH/el/7/AD/40fZY/wC9L/3+f/GkJKyS7E1FQ/ZY/wC9L/3+f/Gj7LH/AHpf+/z/AONAyaiofssf96X/AL/P/jR9lj/vS/8Af5/8aAJqKh+yx/3pf+/z/wCNH2WP+9L/AN/n/wAaAJqKh+yx/wB6X/v8/wDjR9lj/vS/9/n/AMaAJqKh+yx/3pf+/wA/+NH2WP8AvS/9/n/xoALr/Ur/ANdI/wD0MVNVS5tkEQw0v+sQcysf4h71L9lj/vS/9/n/AMaAJqKh+yx/3pf+/wA/+NH2WP8AvS/9/n/xoA5Lxdo/ifWdctEtbXSrzQLcLNJZ3OoS2z3E4bK+YVhkDRrgELxluuQMVX1nwvrmteIrO+/s7QrCaG4glOsW08n22OJMM9uP3Q3qx3rkuAVblM8Htfssf96X/v8AP/jR9lj/AL0v/f5/8aFp/X9f1oD1MWHQ7ubx7ca7qTwPb29qtrpkSElowx3TO2QAGYhFGM/KnuRWTe+BrrXLXxadZuoUu9bT7JaSw5cWtsi/uhyBk7yzsBxlsZOAa7D7LH/el/7/AD/40fZY/wC9L/3+f/Gl0t/Wo763/rQ5fTdH8R/2tf69qkemRap/Zq2NnbW9zJJDlSzl3cxqRuYgYCnAXq2eKP8Awgt/YeHfDv8AZ8lrd61o96b+drp2jjvJpFdZyXCsVyZWIO04wBj07b7LH/el/wC/z/40fZY/70v/AH+f/Gn/AF+N/wAxf1+FvyPNh8Kb+XSdUuDr09jq+ow3itb2flNaR+e7OUBkhZwpJUMy7S20HAwK3G8IanPo/hfRb2/ju9P050m1JpiPMuGiXMUahUVSgkwSSAcRr1JJrrfssf8Ael/7/P8A40fZY/70v/f5/wDGhaaLy/Db8weur8/x3Ob8S6T4l1qz1G0t57CO1862e0jEkkbXEasDPDO4B2q+CoKg8E5ByRUXhLw7feH7XUPtcdnZW91eRyWul2ErSW9kvyghCypjc2WICqATwOpPU/ZY/wC9L/3+f/Gorm2QRDDS/wCsQcysf4h70LT+v67A9TltY8HahqFj40hhmtlbXkRbUuzAJthWM7/l45HbPFOk8N6sfHkOq2EFpplt5qteXEGpTM18gjK7ZLXyxFuyV/ebiwCDB7V1n2WP+9L/AN/n/wAaPssf96X/AL/P/jQtHcHqrHNano+v2fi661vw3Hp139vsY7WeHULmSHymiZyjqUR9wPmtlSF6DDdag8KeCbjwzrsE/wBqjuLSDQ7fTQ2CrtJHJIzNt6BTvGBk46dq6z7LH/el/wC/z/40fZY/70v/AH+f/Ghaf16/5sHr/Xp/kiaiofssf96X/v8AP/jR9lj/AL0v/f5/8aAJqhuv9Sv/AF0j/wDQxR9lj/vS/wDf5/8AGorm2QRDDS/6xBzKx/iHvQBNd2yXlnNbS58uaNo2x1wRg/zrhNH8JeJrJdKF1Jpe7w7pstppjpLIwu5GRUSSZdi+WAqDKqX5Y4Ixz3X2WP8AvS/9/n/xo+yx/wB6X/v8/wDjR3/rv/mw/r+vuOL8RaP4x1m80xJrXRLzS7eGOa7szqE1sLi7Bz8xEMm6FSMheMnG7IGKTWfC+ua14is77+ztCsJobiCU6xbTyfbY4kwz24/dDerHeuS4BVuUzwe1+yx/3pf+/wA/+NH2WP8AvS/9/n/xp9b/AD/r+vIOljz+H4f6r9stdOmawXRLPWJ9ViuUlc3T+Z5h8opsCrhpWBfecqAMDPDNH8F+J9LGklf7G3+G9NnstMcTSH7WzhVRph5Y8tQEUlVL5J6jHPof2WP+9L/3+f8Axo+yx/3pf+/z/wCNJaKy/rS35A9Xd/1rf8zgNM8Da3e2Jg8Syx2V493HqFxqmm6gLiW6uE4QNFNahFjXgqvO0ovfLHV8IeFtR8L2mqrqerS6ib3VWuo94j+VWkB3HZGnzn+IcqMDGOa6r7LH/el/7/P/AI1Fc2yCIYaX/WIOZWP8Q96Fpt/W3+SDf+vX/NnNTeHNWbx9Fq2nwWmmW3nBru4g1KZnvoxGVCyWvliLdkr+83FgEGD2rsKh+yx/3pf+/wA/+NH2WP8AvS/9/n/xo6WDrcmoqH7LH/el/wC/z/40UAf/2Q==)

Write a short analysis of the results.

Linear regression involves finding the equation of the line that best models a set of data points. Comparing the above table, we came to know that the time taken for multithreading program take long time than the simple program for linear regression. Here the time taken by the original program 74.7 ns whereas the time taken by the program after implementing the thread is 237707647.8 ns. This is because there are all total 8 threads and only 4 cores to work on. To complete the small work there has been more workload and the threads are spending the time on waiting the other one to complete it.

# CUDA

## Password Cracking

1. #include <stdio.h>
2. #include <cuda\_runtime\_api.h>
3. #include <time.h>
5. /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*
6. \*
7. \*
8. \* Compile with:
9. \* nvcc -o 2ini\_2dig 2ini\_2dig.cu
10. \*
11. \*
12. \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/
13. \_\_device\_\_ int is\_a\_match(char \*attempt){
14. char password1[] ="BV78";
15. char password2[] ="ET83";
16. char password3[] ="GR61";
17. char password4[] ="SB10";
19. char \*a = attempt;
20. char \*b = attempt;
21. char \*c = attempt;
22. char \*d = attempt;
23. char \*p1 = password1;
24. char \*p2 = password2;
25. char \*p3 = password3;
26. char \*p4 = password4;
28. while(\*a ==\*p1){
29. if(\*a == '\0')
30. {
31. printf("password:%s\n", password1);
32. break;
33. }
34. a++;
35. p1++;
36. }
37. while(\*b ==\*p2){
38. if(\*b == '\0')
39. {
40. printf("password:%s\n", password2);
41. break;
42. }
43. b++;
44. p2++;
45. }
46. while(\*c ==\*p3){
47. if(\*c == '\0')
48. {
49. printf("password:%s\n", password3);
50. break;
51. }
52. c++;
53. p3++;
54. }
55. while(\*d ==\*p4){
56. if(\*d == '\0')
57. {
58. printf("password: %s\n", password4);
59. return 1;
60. }
61. d++;
62. p4++;
63. }
64. return 0;
65. }
67. \_\_global\_\_ void kernel(){
68. char i1, i2;
70. char password[5];
71. password[4] ='\0';
73. int i = blockIdx.x +65;
74. int j = threadIdx.x+65;
75. char firstMatch =i;
76. char secondMatch =j;
78. password[0] =firstMatch;
79. password[1] =secondMatch;
80. for(i1='0'; i1<='9'; i1++){
81. for(i2='0'; i2<='9'; i2++){
82. {
83. password[2] =i1;
84. password[3] =i2;
86. if(is\_a\_match(password)){
87. }
89. }
90. }
91. }
92. }
93. int time\_difference(struct timespec \*start, struct timespec \*finish,long long int \*difference) {
94. long long int ds = finish->tv\_sec - start->tv\_sec;
95. long long int dn = finish->tv\_nsec - start->tv\_nsec;
97. if(dn < 0 ) {
98. ds--;
99. dn += 1000000000;
100. }
101. \*difference = ds \* 1000000000 + dn;
102. return !(\*difference > 0);
103. }

106. int main() {
108. struct timespec start, finish;
109. long long int time\_elapsed;
111. clock\_gettime(CLOCK\_MONOTONIC, &start);
113. kernel<<<26,26>>>();
114. cudaThreadSynchronize();

117. clock\_gettime(CLOCK\_MONOTONIC, &finish);
118. time\_difference(&start, &finish, &time\_elapsed);
119. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
120. (time\_elapsed/1.0e9));
121. return 0;
122. }

 Code Explanation

The NVIDIA graphic is essential to use brute force algorithm and crack password or simply to run this program since CUDA is used. In this program 26\*26 thread is used inside GPU. The program will be executed in the graphics card and display the result by CPU/Host using cudaThreadSynchronize function to synchronize the program with the CPU. Main program is always written in the global function in our case global function is kernel() and it is called by using <<< >>> symbol. We have used simple combination of password instead of using encrypted form as CUDA does not support crypt function.

Kernel ()

It is a global function where the main idea of a program is written. This this function we have defined thread and block to find the 2 initials of the password. And for finding the 2 digit we have used nested loop which will look for all the possible combination.

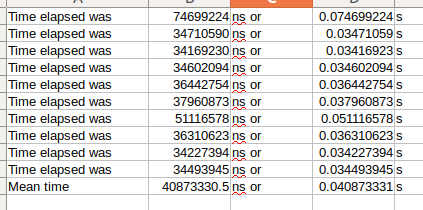
Is a match ()

This function is run in the GUP. So \_\_device \_\_ should be mentioned Infront of the function name. The correct password is inserted in the beginning in this function as a variable. Every password is compared with the attempted password using the loop and comparing each and every character. After the password is found it will return the password.

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

A picture containing crossword puzzle

Description automatically generated



Write a short analysis of the results

Above table shows the mean running time of both simple and CUDA version of password cracking. Compare the table we acknowledge that the mean running time of CUDA program for cracking password is faster than the simple program. This is because, simple program run on the CPU but CUDA program run on GPU which have a greater number of cores than CPU. GPU compose of several parallel execution units and faster memory interfaces compares to CPU. Thus, it is computationally more powerful. This program run 676 threads at a same time in GPU. Mean running time of simple program is 678 sec and CUDA program is 0.04 sec. Hence, we can say that CUDA program is 1000 times faster than simple program. Similarly, in simple program CRYPT function is used where as in CUDA program normal text is use as it does not support CRYPT function. This is also one of the reasons for running CUDA program faster than simple program.

## Image Processing

1. #include <stdio.h>
2. #include <stdlib.h>
3. #include <time.h>
4. #include <GL/glut.h>
5. #include <GL/gl.h>
6. #include <malloc.h>
7. #include <signal.h>
8. #include <cuda\_runtime\_api.h>


12. /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*
13. Displays two grey scale images. On the left is an image that has come from an
14. image processing pipeline, just after colour thresholding. On the right is
15. the result of applying an edge detection convolution operator to the left
16. image. This program performs that convolution.
18. Things to note:
19. - A single unsigned char stores a pixel intensity value. 0 is black, 256 is
20. white.
21. - The colour mode used is GL\_LUMINANCE. This uses a single number to
22. represent a pixel's intensity. In this case we want 256 shades of grey,
23. which is best stored in eight bits, so GL\_UNSIGNED\_BYTE is specified as
24. the pixel data type.
26. To compile adapt the code below wo match your filenames:
27. nvcc -o Image\_processing\_cuda Image\_processing\_cuda.cu -lglut -lGL -lm
29. To result:
30. ./Image\_processing\_cuda
32. \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/
33. #define width 100
34. #define height 72
36. unsigned char image[] = {0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
37. 0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,
38. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
39. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
40. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
41. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
42. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
43. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
44. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,
45. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
46. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
47. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,
48. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
49. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
50. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
51. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
52. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
53. 0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
54. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
55. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
56. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
57. 0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
58. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
59. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
60. 255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,
61. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
62. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
63. 0,0,0,0,0,0,0,255,255,0,0,0,0,255,255,255,255,255,255,
64. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
65. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,
66. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
67. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
68. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,0,0,0,255,255,
69. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
70. 255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
71. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
72. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,0,0,
73. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,
74. 255,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
75. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,
76. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
77. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,
78. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
79. 0,255,255,0,255,255,255,0,0,255,255,255,255,255,255,255,255,255,255,
80. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
81. 255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
82. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
83. 0,0,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,
84. 0,0,0,0,255,255,255,255,255,255,255,255,255,0,0,255,255,255,255,
85. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
86. 255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
87. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
88. 0,0,0,0,0,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
89. 0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,0,
90. 0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
91. 255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,
92. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
93. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,0,
94. 0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,
95. 255,255,255,255,255,0,0,255,255,255,255,255,255,255,255,255,255,255,255,
96. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
97. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
98. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,
99. 255,255,255,255,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
100. 255,255,255,255,255,255,255,255,255,255,255,0,0,255,255,255,255,255,255,
101. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,
102. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
103. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,
104. 255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,255,
105. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,
106. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
107. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
108. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
109. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,
110. 0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
111. 255,255,255,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,
112. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
113. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
114. 0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
115. 0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,
116. 255,255,255,255,255,255,255,255,255,0,0,255,255,255,255,255,255,255,255,
117. 255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,
118. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
119. 0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,
120. 255,255,255,255,255,0,0,0,0,255,255,255,255,255,255,255,255,255,255,
121. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,255,255,
122. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,
123. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
124. 0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,
125. 255,255,255,255,255,255,255,255,255,255,0,0,0,255,255,255,255,255,255,
126. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
127. 255,255,0,0,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
128. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
129. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,
130. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,255,255,255,
131. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
132. 255,255,255,255,255,255,255,0,0,255,255,0,255,255,255,255,0,0,0,
133. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
134. 0,0,0,0,0,0,0,0,0,255,0,0,0,0,0,0,255,255,255,
135. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
136. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
137. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,255,255,255,255,
138. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
139. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
140. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
141. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
142. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,
143. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
144. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
145. 0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
146. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
147. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
148. 255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,
149. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
150. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
151. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
152. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
153. 255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,
154. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
155. 0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,
156. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
157. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
158. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,
159. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
160. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
161. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
162. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
163. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,
164. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
165. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,
166. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
167. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
168. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
169. 255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
170. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
171. 0,0,255,255,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
172. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
173. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
174. 255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,
175. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
176. 0,0,0,0,0,255,255,0,0,0,255,255,255,255,255,255,255,255,255,
177. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
178. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
179. 255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,
180. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
181. 0,0,0,0,0,0,0,0,0,255,0,0,0,0,255,255,255,255,255,
182. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
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377. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
378. 0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
379. 255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,255,255,
380. 255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
381. 0,0,0,0,0,0,255,0,0,0,0,0,0,0,255,0,0,0,0,
382. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
383. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
384. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
385. 0,0,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
386. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
387. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
388. 0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,
389. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,
390. 0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,
391. 0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
392. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
393. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,
394. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
395. 255,255,255,255,255,0,0,0,0,0,255,0,0,0,0,0,0,255,0,
396. 0,0,0,0,0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,
397. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
398. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
399. 0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
400. 255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,
401. 0,0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,
402. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
403. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
404. 0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,
405. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,255,
406. 0,0,0,0,0,0,0,0,0,0,0,255,255,0,0,0,0,0,0,
407. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
408. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
409. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
410. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
411. 255,255,255,255,0,0,0,0,0,0,0,0,0,0,255,0,0,0,0,
412. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
413. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
414. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
415. };

418. unsigned char results[width \* height];
419. //static void key\_pressed(unsigned char key, int x, int y);
420. //void stgint callback(int signal\_number);
421. //static void display();
422. //void tidy\_and\_exit();
424. \_\_global\_\_ void detect\_edges(unsigned char \*in, unsigned char \*out) {
426. unsigned int i = (blockIdx.x\*72) +threadIdx.x;
428. int x;//the pixel of interest
429. int y;//the pixel of interest
430. int b;//the pixels adjacent to x,y used for calculation
431. int d;//the pixels adjacent to x,y used for calculation
432. int f;//the pixels adjacent to x,y used for calculation
433. int h;//the pixels adjacent to x,y used for calculation
434. int r;//the result of calculate
436. y = i / 100;
437. x = i - (100 \* y);
439. if (x == 0 || y == 0 || x == width - 1 || y == height - 1) {
440. out[i] = 0;
441. } else {
442. b = i + 100;
443. d = i - 1;
444. f = i + 1;
445. h = i - 100;
447. r = (in[i] \* 4) + (in[b] \* -1) + (in[d] \* -1) + (in[f] \* -1) + (in[h] \* -1);
449. if (r > 0) { // if the result is positive this is an edge pixel
450. out[i] = 255;
451. } else {
452. out[i] = 0;
453. }
454. }
455. }



460. void tidy\_and\_exit() {
461. exit(0);
462. }
464. void sigint\_callback(int signal\_number){
465. printf("\nInterrupt from keyboard\n");
466. tidy\_and\_exit();
467. }
469. static void display() {
470. glClear(GL\_COLOR\_BUFFER\_BIT);
471. glRasterPos4i(-1, -1, 0, 1);
472. glDrawPixels(width, height, GL\_LUMINANCE, GL\_UNSIGNED\_BYTE, image);
473. glRasterPos4i(0, -1, 0, 1);
474. glDrawPixels(width, height, GL\_LUMINANCE, GL\_UNSIGNED\_BYTE, results);
475. glFlush();
476. }
478. static void key\_pressed(unsigned char key, int x, int y) {
479. switch(key){
480. case 27: // escape
481. tidy\_and\_exit();
482. break;
483. default:
484. printf("\nPress escape to exit\n");
485. break;
486. }
487. }
488. int time\_difference(struct timespec \*start, struct timespec \*finish,
489. long long int \*difference) {
490. long long int ds = finish->tv\_sec - start->tv\_sec;
491. long long int dn = finish->tv\_nsec - start->tv\_nsec;
493. if(dn < 0 ) {
494. ds--;
495. dn += 1000000000;
496. }
497. \*difference = ds \* 1000000000 + dn;
498. return !(\*difference > 0);
499. }
501. int main(int argc, char \*\*argv) {



506. unsigned char \*d\_results;
507. unsigned char \*d\_image;

510. cudaMalloc((void\*\*)&d\_image, sizeof(unsigned char) \* (width \* height) );
511. cudaMalloc((void\*\*)&d\_results, sizeof(unsigned char) \* (width \* height));
512. cudaMemcpy(d\_image, &image, sizeof(unsigned char) \* (width \* height), cudaMemcpyHostToDevice);

515. signal(SIGINT, sigint\_callback);
517. printf("image dimensions %dx%d\n", width, height);

520. struct timespec start, finish;
521. long long int time\_elapsed;
523. clock\_gettime(CLOCK\_MONOTONIC, &start);
524. printf("image dimensions %dx%d\n", width, height);
525. detect\_edges <<<100, 72>>>(d\_image, d\_results);
526. cudaThreadSynchronize();
527. cudaMemcpy(&results, d\_results, sizeof(unsigned char) \* (width \* height), cudaMemcpyDeviceToHost);
528. clock\_gettime(CLOCK\_MONOTONIC, &finish);
530. time\_difference(&start, &finish, &time\_elapsed);
531. printf("Time elapsed was %lldns or %0.9lfs\n",
532. time\_elapsed, (time\_elapsed/1.0e9));


536. cudaFree(&d\_image);
537. cudaFree(&d\_results);


541. glutInit(&argc, argv);
542. glutInitWindowSize(width \* 2,height);
543. glutInitDisplayMode(GLUT\_SINGLE | GLUT\_LUMINANCE);
545. glutCreateWindow("6CS005 Image Progessing Courework");
546. glutDisplayFunc(display);
547. glutKeyboardFunc(key\_pressed);
548. glClearColor(0.0, 1.0, 0.0, 1.0);

551. glutMainLoop();
552. tidy\_and\_exit();

555. return 0;
556. }

Code explanation

CUDA is used to process the image in the GPU which is done by using the library function of CUDA. CudaMALLOC is first used to allocate the byte sized memory on the host and then copied that memory to device using cudaMemcpyHostToDevice library. The first two memory spaces are allocated where one is used for the image to be sent and the next for storing the resulted image. The memory sized of the program will generally be the total number of pixels of our image.

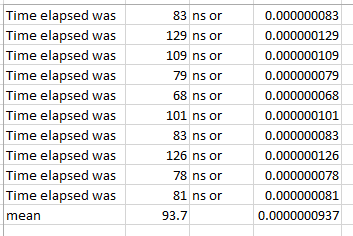
detect\_edges <<<100, 72>>>

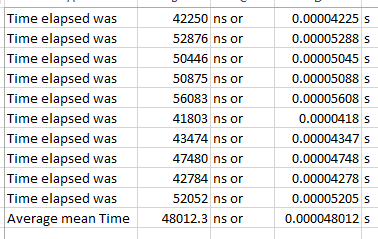
detect\_edegs is the global function in this program which is invoked by using <<<>>> symbol. This function used 72 blocks and each block contain 100 threads. In total there are 7200 threads which are running in GPU parallelly.

display()

This function is used to displays two grey scale images.

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





Write a short analysis of the results

The table above shows the mean running time of simple program and CUDA program for image processing. The mean time for the original version was 93.7ns whereas the mean time for the CUDA program is 48012.3 ns. The difference between them was 47918.6 ns. In this case we find that programmed executed in GPU is slower than the one that is runs in CPU. This happens because the data of image should be copped form host to device and in device the program is executed. After executing device should again pass the data to host for displaying. This process makes CUDA program slower than original program.

## Linear Regression

1. #include <stdio.h>
2. #include <math.h>
3. #include <time.h>
4. #include <unistd.h>
5. #include <cuda\_runtime\_api.h>
6. #include <errno.h>
7. #include <unistd.h>
8. /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*
9. \*
10. \*
11. \* To compile:
12. \* nvcc -o linearcuda linear\_cuda.cu -lm
13. \*
14. \* To run:
15. \* ./linearcuda
16. \*
17. \*
18. \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/
20. typedef struct point\_t{
21. double x;
22. double y;
23. }point\_t;
25. int n\_data = 1000;
26. \_\_device\_\_ int d\_n\_data =1000;
28. point\_t data[] = {
29. {72.12,100.78},{65.40,107.86},{82.27,131.60},{82.31,122.34},
30. {89.41,121.50},{71.37,113.51},{82.62,112.38},{69.57,102.96},
31. {65.38,99.27},{84.50,138.85},{87.18,114.17},{73.03,109.21},
32. {67.26,102.06},{72.25,113.23},{61.28,101.59},{41.60,84.24},
33. {40.14,57.03},{15.24,45.58},{61.88,89.90},{34.89,72.77},
34. { 8.91,36.34},{30.45,46.18},{67.93,89.35},{68.82,112.80},
35. {63.96,99.32},{32.36,56.12},{42.20,63.66},{24.47,60.75},
36. { 1.96,28.62},{41.42,68.41},{34.49,73.14},{ 8.03,22.13},
37. {80.55,117.79},{85.54,130.80},{68.99,103.13},{99.32,144.79},
38. {91.71,153.61},{71.17,108.40},{85.28,120.11},{99.52,128.68},
39. {13.24,31.67},{ 5.19,40.15},{ 9.84,57.36},{29.42,54.01},
40. {89.68,126.25},{29.45,41.30},{79.63,132.59},{71.88,107.31},
41. {20.05,48.38},{40.98,54.11},{56.55,63.61},{77.22,114.17},
42. {63.86,88.10},{92.93,134.84},{56.84,101.20},{34.31,71.18},
43. {93.89,116.43},{38.02,63.78},{61.25,94.71},{71.02,103.42},
44. {95.05,142.82},{96.24,133.50},{19.50,50.92},{41.14,70.59},
45. {91.49,134.05},{54.05,98.31},{36.59,68.48},{91.14,130.45},
46. {44.76,88.98},{77.28,138.16},{64.80,96.33},{43.25,70.08},
47. {55.55,95.70},{ 3.77,39.03},{ 3.23,44.69},{86.72,127.42},
48. {84.62,131.54},{26.13,71.24},{61.22,98.22},{53.90,96.07},
49. {64.81,109.35},{91.66,116.79},{53.65,104.81},{38.42,66.16},
50. {62.33,112.41},{ 7.41,29.86},{41.59,57.59},{56.49,91.60},
51. {15.94,42.82},{97.46,140.29},{57.17,85.11},{26.94,45.86},
52. {73.14,96.37},{18.61,60.58},{15.69,44.16},{20.79,33.86},
53. {65.02,106.03},{38.09,72.71},{87.15,116.68},{77.45,123.08},
54. {90.47,126.33},{26.80,44.96},{75.94,119.76},{33.83,69.11},
55. {63.59,103.98},{38.05,72.36},{68.28,110.76},{ 3.34,54.22},
56. {45.40,92.84},{78.37,113.49},{27.11,46.46},{32.32,68.44},
57. {20.97,30.90},{37.92,75.11},{96.85,130.96},{69.40,95.17},
58. { 3.29,30.06},{64.41,103.44},{15.80,52.64},{61.76,97.79},
59. { 1.62,33.98},{29.03,58.02},{18.74,34.93},{25.41,73.73},
60. {28.78,65.94},{14.64,50.31},{82.85,133.70},{41.62,90.32},
61. {99.28,144.95},{90.16,133.18},{40.45,77.72},{ 1.79,50.44},
62. {31.80,62.71},{26.30,40.89},{47.57,83.15},{17.78,44.90},
63. {69.48,93.13},{87.98,126.95},{69.84,106.00},{37.06,61.61},
64. {90.65,133.97},{10.73,46.60},{38.84,79.90},{ 4.75,33.89},
65. {48.99,89.31},{ 2.51,47.09},{34.99,86.40},{29.79,54.52},
66. {91.30,133.72},{74.12,122.86},{90.93,141.88},{51.14,89.93},
67. {84.53,142.49},{26.84,58.79},{ 6.95,20.98},{49.80,85.14},
68. {22.82,57.02},{44.08,89.32},{22.28,48.72},{21.12,50.68},
69. {65.69,93.93},{27.84,39.97},{ 1.92,40.39},{ 9.36,33.54},
70. {88.10,123.02},{18.15,63.84},{21.80,39.76},{64.42,101.03},
71. { 2.23,22.52},{55.68,99.56},{37.55,87.77},{74.23,104.87},
72. {11.96,37.30},{23.60,45.84},{11.13,34.32},{ 9.05,48.79},
73. {56.11,100.21},{19.31,54.44},{ 6.27,16.17},{64.65,101.39},
74. {50.25,77.59},{69.33,95.12},{47.52,87.79},{28.97,65.98},
75. {71.56,95.30},{19.71,41.47},{57.66,96.65},{41.07,74.10},
76. {35.08,79.46},{40.80,87.01},{ 0.31,19.82},{90.78,111.55},
77. {34.39,72.03},{99.97,139.40},{30.86,73.03},{14.37,50.15},
78. { 6.11,42.76},{21.75,80.30},{89.94,127.56},{10.86,42.40},
79. {13.07,42.98},{84.47,147.14},{83.44,132.18},{32.24,63.57},
80. {66.93,102.41},{34.48,68.96},{ 3.46,22.82},{94.84,130.83},
81. {49.41,107.26},{71.64,99.82},{47.28,80.62},{39.17,68.77},
82. {58.05,108.35},{69.27,109.81},{47.64,73.34},{34.64,73.15},
83. {22.86,46.34},{37.76,66.19},{ 3.12,39.11},{60.59,111.05},
84. {91.99,122.76},{96.60,138.86},{ 3.58,23.35},{22.81,60.18},
85. {13.93,21.32},{69.51,106.41},{19.57,43.39},{79.11,115.68},
86. {80.89,124.36},{44.42,57.78},{33.28,73.04},{21.45,49.88},
87. {70.57,113.77},{45.63,65.60},{55.99,72.21},{21.62,41.47},
88. {61.74,98.99},{ 9.30,29.77},{75.32,106.74},{27.97,73.44},
89. {74.77,115.98},{42.93,82.67},{92.32,138.05},{25.55,64.34},
90. { 0.48,23.51},{79.52,111.52},{52.83,70.58},{51.45,87.28},
91. {62.72,90.41},{ 4.16,40.60},{70.13,115.25},{55.96,97.34},
92. {93.88,154.09},{46.21,90.04},{34.75,51.46},{54.45,89.56},
93. {80.69,129.36},{45.14,73.00},{47.34,85.69},{70.16,118.02},
94. { 4.26,17.14},{61.56,98.04},{15.95,28.56},{74.06,118.48},
95. {65.29,99.71},{19.08,55.64},{37.82,72.36},{58.22,103.93},
96. {50.52,82.15},{26.25,60.91},{97.77,123.91},{39.13,68.03},
97. {15.09,41.88},{32.61,61.64},{11.23,22.85},{61.92,98.02},
98. {73.63,126.32},{35.12,54.74},{12.98,42.69},{83.87,128.60},
99. {45.65,78.81},{42.85,90.57},{76.74,117.53},{19.05,49.60},
100. {69.03,104.16},{23.66,54.97},{52.85,85.94},{82.07,128.27},
101. {74.77,111.22},{95.04,136.69},{40.49,49.53},{ 4.16,28.40},
102. { 7.69,51.29},{29.37,80.82},{86.06,122.19},{ 3.92,23.24},
103. {62.76,108.89},{27.12,54.24},{10.24,33.84},{79.86,107.97},
104. {57.09,85.27},{10.29,54.38},{53.50,82.98},{12.83,50.29},
105. { 2.09,13.69},{88.73,135.16},{42.72,87.10},{40.20,91.88},
106. {40.10,76.49},{80.22,133.65},{57.55,93.99},{29.34,69.08},
107. { 2.90,41.26},{44.60,82.03},{47.93,89.05},{98.17,123.11},
108. {17.21,45.91},{42.37,79.83},{90.89,119.42},{ 7.81,36.64},
109. {76.14,123.86},{47.79,83.40},{95.27,144.30},{44.13,98.20},
110. {19.97,37.36},{90.66,131.96},{75.41,117.80},{57.14,107.91},
111. {25.92,41.69},{90.86,130.36},{44.78,79.02},{23.00,29.10},
112. {91.67,118.13},{26.55,51.18},{41.60,74.91},{ 0.39, 6.79},
113. {86.31,102.08},{20.43,37.80},{ 5.39,28.65},{12.63,24.33},
114. {22.60,42.79},{ 1.77,14.54},{74.10,113.64},{54.46,87.67},
115. {18.64,49.32},{93.97,116.30},{42.62,87.04},{13.37,30.16},
116. {74.50,104.62},{18.28,67.85},{76.98,107.84},{25.89,57.35},
117. {13.52,42.87},{61.26,97.78},{ 5.97,31.34},{91.99,137.43},
118. {20.38,58.23},{ 9.59,31.56},{79.41,126.40},{89.90,134.36},
119. {73.18,111.44},{61.51,111.41},{99.96,147.82},{72.55,113.52},
120. {66.21,110.93},{36.47,59.41},{65.58,93.39},{24.93,51.71},
121. {58.00,95.89},{49.83,83.52},{53.35,89.98},{83.97,129.85},
122. {57.33,106.86},{53.94,98.13},{98.02,144.26},{47.28,72.52},
123. {45.48,100.70},{80.69,147.66},{96.14,140.01},{82.69,120.80},
124. {79.73,136.89},{11.42,27.51},{88.91,138.59},{25.53,51.26},
125. { 2.49,37.14},{63.89,93.28},{90.96,138.02},{15.27,53.03},
126. {25.39,51.31},{31.77,55.54},{88.25,124.46},{67.66,108.26},
127. {90.23,112.02},{17.40,43.85},{78.38,137.07},{96.28,149.45},
128. {77.38,120.54},{56.49,107.27},{99.00,141.67},{36.35,58.18},
129. {97.41,132.64},{15.03,48.28},{42.48,81.20},{62.95,105.32},
130. {99.76,147.11},{85.18,140.95},{99.23,131.84},{21.09,44.44},
131. {45.12,75.22},{80.36,119.71},{61.37,84.74},{82.64,128.58},
132. {70.34,108.16},{83.63,116.26},{47.73,67.57},{17.56,48.42},
133. {23.26,42.12},{41.81,82.17},{18.48,33.63},{39.11,70.14},
134. {84.20,123.97},{67.20,113.97},{52.74,87.79},{81.66,131.54},
135. {45.90,93.69},{20.82,34.77},{86.35,122.38},{78.93,106.82},
136. {10.56,44.66},{51.20,104.61},{93.79,131.97},{15.71,43.06},
137. {99.16,156.47},{90.70,135.27},{41.85,77.91},{73.41,106.66},
138. {57.51,108.55},{53.06,115.27},{25.72,67.45},{ 8.03,27.74},
139. {57.91,101.56},{35.87,57.47},{98.33,145.81},{50.96,76.84},
140. {57.86,102.10},{17.21,44.21},{95.62,154.59},{76.92,114.77},
141. {25.32,60.66},{43.60,68.34},{42.68,73.98},{60.36,84.81},
142. { 9.06,42.91},{ 4.16,18.44},{54.14,97.87},{ 4.87,35.92},
143. {75.38,112.62},{41.37,68.92},{88.16,163.96},{16.79,41.87},
144. { 9.77,40.62},{69.66,125.12},{70.35,118.66},{71.99,97.87},
145. {63.66,111.29},{ 2.01,19.46},{64.63,122.89},{48.39,84.19},
146. {28.15,64.69},{46.17,83.91},{25.12,45.94},{82.23,118.70},
147. {57.69,95.98},{24.42,62.91},{15.81,35.58},{75.28,106.87},
148. {95.74,133.25},{67.78,107.42},{80.89,128.72},{10.39,38.37},
149. {15.31,35.73},{61.45,110.46},{11.15,44.99},{30.80,63.26},
150. {84.29,122.39},{29.17,47.34},{80.68,138.44},{81.17,117.86},
151. { 8.47,32.78},{41.26,74.09},{43.50,71.18},{34.48,68.61},
152. {30.63,68.05},{88.63,137.28},{71.56,116.97},{21.03,39.12},
153. {88.20,116.24},{ 8.52,30.24},{95.79,137.27},{78.66,104.62},
154. {72.44,94.21},{71.60,106.34},{72.11,114.18},{34.50,59.18},
155. {22.85,60.95},{18.43,40.91},{69.24,119.69},{91.84,142.06},
156. {34.41,69.95},{95.06,136.92},{67.93,100.93},{46.96,71.82},
157. {63.92,102.14},{ 1.62,29.66},{95.24,133.60},{43.10,80.88},
158. {21.83,73.25},{35.01,62.42},{20.05,55.19},{18.64,45.92},
159. {40.28,75.26},{34.54,63.38},{84.74,117.68},{90.38,144.87},
160. { 9.91,24.87},{62.97,102.14},{34.40,79.20},{67.34,89.48},
161. {48.53,85.13},{24.57,51.59},{81.95,117.78},{22.23,49.77},
162. {75.86,125.20},{60.45,99.78},{19.93,35.57},{48.62,78.46},
163. {88.49,120.71},{13.33,40.67},{52.03,93.38},{38.43,80.28},
164. { 2.56,17.00},{18.39,58.10},{58.81,88.08},{75.76,96.69},
165. {69.78,98.83},{96.47,146.81},{47.32,79.89},{21.90,46.54},
166. {52.39,83.38},{75.49,107.96},{50.14,80.51},{41.54,73.80},
167. {76.07,117.48},{27.00,73.59},{81.59,122.88},{21.74,39.55},
168. {60.05,105.04},{75.68,102.72},{40.41,79.01},{ 0.32,24.82},
169. {50.06,106.14},{98.69,139.50},{64.17,109.26},{42.74,78.53},
170. {39.52,71.78},{55.14,97.37},{25.19,39.08},{99.31,142.63},
171. {67.50,91.86},{90.92,152.17},{81.99,129.38},{77.28,124.08},
172. {29.38,69.15},{ 3.81,41.93},{ 9.72,41.83},{25.75,53.09},
173. {57.28,85.11},{69.50,116.90},{20.00,51.46},{63.00,72.32},
174. {67.06,102.20},{37.85,64.86},{81.40,114.28},{13.32,58.41},
175. {67.21,103.77},{63.73,109.66},{91.43,141.66},{54.83,88.07},
176. {68.03,112.67},{ 0.51,27.76},{ 2.17,38.05},{36.26,66.58},
177. {72.67,116.52},{98.28,136.37},{85.27,128.64},{90.26,136.47},
178. {60.31,95.24},{32.77,58.94},{ 3.52,24.75},{15.98,45.49},
179. {94.25,145.90},{ 8.13,29.89},{61.13,81.38},{44.14,77.64},
180. {63.53,100.35},{49.35,97.92},{ 4.98,32.12},{25.53,57.45},
181. { 8.63,41.62},{24.23,56.27},{93.30,137.92},{43.72,71.72},
182. {54.15,89.12},{ 3.42,36.34},{57.75,85.68},{51.90,87.74},
183. {85.14,137.82},{99.27,173.87},{82.53,124.94},{15.38,44.42},
184. {66.66,108.56},{64.12,99.41},{39.08,73.77},{25.42,58.25},
185. { 1.29,36.39},{98.72,148.84},{70.09,112.06},{ 8.51,27.00},
186. {85.92,124.74},{88.32,127.04},{51.79,74.58},{36.46,62.45},
187. {49.29,85.33},{14.06,30.58},{24.83,34.82},{42.85,87.06},
188. {34.47,76.96},{59.16,90.44},{ 1.02,32.32},{61.80,108.22},
189. {72.52,95.83},{65.40,99.49},{53.32,93.79},{74.22,117.61},
190. {53.86,88.31},{39.84,80.11},{79.28,117.86},{34.57,76.73},
191. {21.69,55.55},{99.87,129.34},{72.12,108.86},{75.08,106.64},
192. {70.71,106.00},{18.35,67.45},{37.42,66.71},{ 0.70, 9.02},
193. {56.79,86.75},{74.04,100.45},{53.40,82.23},{42.13,70.45},
194. {82.43,123.55},{91.65,131.55},{94.99,153.70},{62.14,84.17},
195. {99.71,151.07},{33.24,73.77},{48.87,76.91},{68.57,118.95},
196. {14.28,46.22},{18.17,41.01},{95.93,133.32},{ 5.06,33.23},
197. {57.58,95.47},{18.71,39.10},{90.19,136.73},{26.98,50.08},
198. {11.36,26.14},{62.70,98.59},{49.32,80.54},{99.97,149.27},
199. {83.40,132.00},{25.30,48.62},{79.25,117.83},{81.09,109.23},
200. {31.46,51.02},{14.26,32.26},{33.53,52.63},{ 9.42,47.16},
201. {67.40,109.90},{18.56,32.79},{34.51,75.14},{49.00,77.38},
202. {15.69,50.80},{23.09,40.32},{32.03,67.86},{13.60,40.35},
203. {19.21,60.16},{78.56,111.57},{80.72,131.02},{50.19,79.64},
204. {55.60,81.78},{ 6.37,43.37},{42.78,74.85},{60.48,113.67},
205. {44.44,89.27},{54.02,90.24},{73.51,101.74},{16.41,56.73},
206. {70.94,104.90},{32.03,66.91},{13.12,49.71},{50.16,85.64},
207. {41.31,68.88},{69.25,123.25},{24.97,69.28},{40.80,86.30},
208. {32.28,67.01},{90.77,142.80},{66.77,104.70},{24.06,56.12},
209. {49.16,89.52},{46.10,95.56},{51.79,94.01},{56.11,100.66},
210. {88.49,126.71},{ 1.28,21.35},{35.55,64.10},{18.79,29.74},
211. { 5.40,40.02},{92.32,129.89},{21.13,47.05},{ 5.14,32.16},
212. {60.89,104.41},{43.45,76.07},{98.91,160.53},{99.31,155.80},
213. {74.71,121.53},{62.33,98.98},{58.66,101.10},{51.51,93.03},
214. {51.69,90.42},{19.47,31.22},{85.75,108.87},{64.20,100.48},
215. {96.60,142.66},{67.99,102.48},{68.37,120.07},{29.81,44.77},
216. {96.55,142.74},{30.59,43.25},{73.94,108.44},{49.77,88.88},
217. {59.48,98.21},{41.21,61.86},{38.63,83.41},{86.98,140.40},
218. {93.34,134.69},{87.92,119.52},{40.93,61.87},{ 2.43,30.68},
219. {50.74,71.81},{37.13,52.43},{ 1.50,22.18},{99.06,143.48},
220. { 1.67,27.67},{ 0.18,10.50},{54.13,77.05},{46.19,88.91},
221. {91.13,144.49},{ 8.95,28.33},{85.69,122.61},{50.30,95.60},
222. {48.63,103.49},{67.99,100.19},{69.21,112.13},{11.26,34.99},
223. {25.78,58.73},{84.35,112.36},{46.80,79.68},{69.54,117.99},
224. {40.30,74.33},{79.97,118.95},{23.28,55.71},{32.62,78.92},
225. {21.86,37.01},{ 5.07,22.57},{94.41,146.15},{40.14,60.81},
226. {95.80,125.35},{91.34,131.68},{72.55,113.56},{40.13,71.59},
227. {98.06,145.27},{90.55,144.08},{71.26,121.81},{33.85,71.13},
228. {85.74,142.63},{57.93,91.78},{ 7.63,39.30},{83.72,128.26},
229. {10.89,46.78},{39.79,66.98},{98.84,146.32},{84.62,123.91},
230. {23.16,31.94},{86.36,134.79},{44.19,63.74},{ 0.39,24.19},
231. {64.22,96.97},{66.47,103.78},{ 1.73,17.52},{22.25,36.77},
232. {31.88,59.39},{15.60,30.03},{16.08,41.91},{83.11,129.19},
233. {72.61,122.52},{19.02,41.06},{56.90,87.53},{65.85,97.02},
234. {81.40,120.35},{64.90,104.44},{73.35,119.00},{ 8.49,40.31},
235. {31.20,65.32},{28.29,75.05},{72.51,120.90},{20.42,48.84},
236. {71.46,111.59},{33.98,50.46},{72.48,111.29},{75.56,113.00},
237. {58.65,95.16},{23.66,44.95},{95.08,139.46},{80.12,115.20},
238. {67.77,101.97},{56.06,99.08},{99.03,138.47},{48.26,74.79},
239. {25.95,39.30},{85.20,137.70},{69.31,104.19},{86.19,122.91},
240. {37.99,87.47},{72.06,116.90},{ 5.66,28.92},{27.77,52.05},
241. {31.89,60.32},{18.01,48.92},{37.21,65.49},{73.76,107.20},
242. { 0.32,-0.71},{93.75,133.48},{69.11,109.63},{11.01,55.84},
243. {43.48,73.99},{20.76,57.44},{75.50,105.00},{98.74,150.46},
244. {40.75,90.93},{61.67,103.30},{93.48,155.96},{35.52,61.62},
245. {32.30,78.52},{28.92,49.61},{60.97,87.11},{13.59,47.58},
246. { 9.43,26.07},{58.00,107.90},{99.86,151.90},{34.01,57.82},
247. {39.02,59.14},{33.64,74.99},{ 2.28,20.21},{55.00,90.93},
248. {55.77,85.94},{79.17,134.03},{63.16,106.70},{17.58,32.28},
249. {24.29,34.68},{83.91,132.35},{96.44,129.86},{61.95,93.66},
250. {14.86,25.10},{15.53,33.29},{15.69,42.47},{80.60,126.11},
251. {16.01,46.33},{26.54,74.55},{ 2.67,37.10},{74.63,96.98},
252. {38.06,59.99},{56.59,96.87},{78.88,120.95},{87.56,121.75},
253. {73.54,119.27},{16.84,44.09},{44.24,89.36},{76.02,123.64},
254. {98.41,115.45},{12.11,48.19},{30.70,60.41},{55.51,100.49},
255. { 0.26,37.11},{83.43,124.44},{49.92,111.30},{65.55,99.48},
256. {77.61,119.44},{62.44,95.52},{21.80,61.06},{20.99,60.54},
257. {93.10,129.45},{54.96,91.05},{10.22,48.48},{66.77,108.83},
258. {40.83,87.14},{13.54,35.77},{31.44,62.92},{79.69,110.30},
259. {67.07,100.59},{28.81,78.71},{52.95,97.30},{39.89,81.67},
260. {58.79,75.89},{34.35,51.29},{38.03,64.97},{87.87,130.19},
261. {39.73,52.43},{ 1.64,31.22},{91.15,147.58},{54.08,101.10},
262. {53.53,74.54},{54.24,104.47},{15.04,51.28},{79.06,114.59},
263. {93.83,138.37},{94.89,122.18},{52.63,86.22},{27.83,68.05},
264. {54.51,94.07},{23.83,58.00},{86.88,141.66},{10.42,31.81},
265. {55.43,84.31},{45.04,85.30},{95.69,121.78},{17.28,35.32},
266. { 3.17,33.76},{51.61,69.81},{27.37,64.13},{88.92,160.98},
267. {31.40,64.46},{33.35,59.91},{82.48,128.89},{50.46,98.13},
268. {78.73,113.68},{70.08,115.27},{98.65,142.28},{ 9.15,50.95},
269. {16.74,35.73},{32.92,72.02},{ 1.29,18.94},{75.79,123.45},
270. {32.94,59.92},{61.72,81.50},{42.39,91.90},{70.15,108.81},
271. { 2.90,29.10},{59.68,87.41},{69.85,108.66},{71.21,107.81},
272. {24.09,46.47},{44.51,76.59},{ 7.30,34.83},{58.93,99.24},
273. { 1.24,22.60},{84.27,132.21},{54.11,87.19},{39.18,75.93},
274. {90.81,155.72},{67.68,88.19},{67.14,84.53},{53.98,86.47},
275. {67.28,106.68},{ 8.49,36.74},{34.96,62.55},{59.01,82.94},
276. {64.78,101.77},{66.24,110.82},{75.81,131.28},{62.82,76.02},
277. {73.95,116.37},{20.40,38.76},{45.06,84.65},{47.64,82.81},
278. {30.85,64.41},{77.10,112.67},{ 8.12,32.76},{39.56,53.41}
279. };
280. double residual\_error(double x, double y, double m, double c) {
281. double e = (m \* x) + c - y;
282. return e \* e;
283. }
284. \_\_device\_\_ double d\_residual\_error(double x, double y, double m, double c) {
285. double e = (m \* x) + c - y;
286. return e \* e;
287. }
288. double rms\_error(double m, double c) {
289. int i;
290. double mean;
291. double error\_sum = 0;
293. for(i=0; i<n\_data; i++) {
294. error\_sum += residual\_error(data[i].x, data[i].y, m, c);
295. }
297. mean = error\_sum / n\_data;
299. return sqrt(mean);
300. }
301. \_\_global\_\_ void d\_rms\_error(double \*m, double \*c,double \*error\_sum\_arr,point\_t \*d\_data) {
302. int i = threadIdx.x + blockIdx.x \*blockDim.x;
303. error\_sum\_arr[i] = d\_residual\_error(d\_data[i].x,d\_data[i].y, \*m, \*c);
304. }
306. int time\_difference(struct timespec \*start, struct timespec \*finish, long long int \*difference)
307. {
308. long long int ds = finish->tv\_sec - start->tv\_sec;
309. long long int dn = finish->tv\_nsec - start->tv\_nsec;
311. if(dn < 0){
312. ds--;
313. dn += 1000000000;
314. }
315. \*difference = ds \* 1000000000 + dn;
316. return !(\*difference > 0);
317. }


321. int main(){
322. int i;
323. double bm = 1.3;
324. double bc = 10;
325. double be;
326. double dm[8];
327. double dc[8];
328. double e[8];
329. double step = 0.01;
330. double best\_error = 999999999;
331. int best\_error\_i;
332. int minimum\_found = 0;
334. double om[] = {0,1,1, 1, 0,-1,-1,-1};
335. double oc[] = {1,1,0,-1,-1,-1, 0, 1};
337. struct timespec start, finish;
338. long long int time\_elapsed;
339. clock\_gettime(CLOCK\_MONOTONIC, &start);
340. cudaError\_t error;

343. double \*d\_dm;
344. double \*d\_dc;
345. double \*d\_error\_sum\_arr;
346. point\_t \*d\_data;
348. be= rms\_error(bm,bc);


352. while(!minimum\_found) {
353. for(i=0;i<8;i++) {
354. dm[i] = bm + (om[i] \* step);
355. dc[i]= bc + (oc[i] \* step);
356. }

359. for(i=0;i<8;i++){
360. double h\_error\_sum\_arr[1000];
362. double error\_sum\_total;
363. double error\_sum\_mean;
365. d\_rms\_error <<<100,10>>>(&d\_dm[i],&d\_dc[i],d\_error\_sum\_arr,d\_data);
366. cudaThreadSynchronize();
367. error =cudaMemcpy(&h\_error\_sum\_arr,d\_error\_sum\_arr,(sizeof(double) \*1000),
368. cudaMemcpyDeviceToHost);
369. if(error){
370. fprintf(stderr,"cudaMemcpy to error\_sum returned %d %s\n",error,
371. cudaGetErrorString(error));
372. }
373. for(int j=0;j<n\_data;j++){
374. error\_sum\_total+= h\_error\_sum\_arr[j];
375. }
376. error\_sum\_mean = error\_sum\_total / n\_data;
377. e[i] =sqrt(error\_sum\_mean);
379. if(e[i] < best\_error){
380. best\_error = e[i];
381. error\_sum\_total +=h\_error\_sum\_arr[i];
382. }
383. error\_sum\_mean = error\_sum\_total /n\_data;//431
384. e[i] = sqrt(error\_sum\_mean); //432
386. if(e[i]<best\_error){ //434
387. best\_error = e[i];
388. best\_error\_i = i;
389. }
390. error\_sum\_total = 0; //438
391. }
392. if(best\_error <be){
393. be=best\_error;
394. bm =dm[best\_error\_i];
395. bc= dc[best\_error\_i];
396. }else {
397. minimum\_found = 1;
398. }
399. }

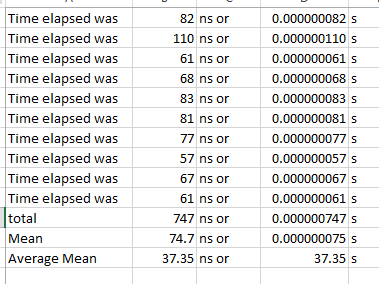

403. printf("minimum m,c is %lf,%lf with error %lf\n", bm, bc, be);
405. clock\_gettime(CLOCK\_MONOTONIC, &finish);
406. time\_difference(&start, &finish, &time\_elapsed);
407. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
408. (time\_elapsed/1.0e9));
410. return 0;
411. }
412. ;

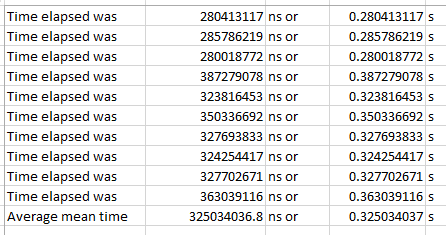
Code Explanation:

This program takes an initial estimate of m and c and finds the associated rms error. It is then as a base to generate and evaluate 8 new estimates which are steps in different directions in m-c space. The best estimate is then used as the base for another iteration of "generate and evaluate". This continues until none of the new estimates are better than the base. This is a gradient search for a minimum in mc-space.

The slope and the y-intercept are found using CUDA. For all the variables of the original programs the memory is allocated using cudaMalloc and transferred to GPU using cudaMemcpy. Using the similar approaches but on the GPU the program finds the possible value of slope and constant. In this program d\_rms\_error is a global function which will run in the device/ GPU. After the code is executed in the GPU we must free the CUDA by using cudaFree.

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





Write a short analysis of the results

Above table shows the mean running time of simple program and CUDA version of linear regression. The mean running time of linear program run in CPU is 74.7 ns and the CUDA program which runs in GPU is 325034036.8 ns. It is clear that the program run in CPU is faster than that of GPU. When we run the program in GPU we need to copy the data from CPU To GUP which takes more time. While doing it in the CPU version it requires minimum time as the program itself is very small. To conclude, if the numbers of data to be proceeding are lower than it will take more time even after running 1000 threads.

# MPI

## Password Cracking

1. #include <stdio.h>
2. #include <string.h>
3. #include <stdlib.h>
4. #include <crypt.h>
5. #include <time.h>
6. #include <mpi.h>
7. #include <unistd.h>
8. #include <pthread.h>
9. /\*
10. To compile:
11. mpicc -o MPI\_passworkCrack MPI\_passworkCrack.c -lcrypt
13. To run 3 processes on this computer:
14. mpirun -n 3 ./MPI\_passworkCrack
15. \*/
17. int n\_passwords = 4;
19. char \*encrypted\_passwords[] = {
20. "$6$KB$0G24VuNaA9ApVG4z8LkI/OOr9a54nBfzgQjbebhqBZxMHNg0HiYYf1Lx/HcGg6q1nnOSArPtZYbGy7yc5V.wP/",
21. "$6$KB$VDUCASt5S88l82JzexhKDQLeUJ5zfxr16VhlVwNOs0YLiLYDciLDmN3QYAE80UIzfryYmpR.NFmbZvAGNoaHW.",
22. "$6$KB$0n1YjoLnJBuAdeBsYFW3fpZzMPP8xycQbEj35GvoerMnEkWIAKnbUBAb70awv5tfHylWkVzcwzHUNy/7l7I1c/",
23. "$6$KB$HKffNNiGzngqYueF89z3gwWZMg.xUBIz/00QSCbgwKtRHmwUbZX6jTH4VUAg3L3skaO8qtNf5LE7WP39jQ7ZJ0"
24. };

27. /\*\*
28. Required by lack of standard function in C.
29. \*/
31. void substr(char \*dest, char \*src, int start, int length){
32. memcpy(dest, src + start, length);
33. \*(dest + length) = '\0';
34. }
36. /\*\*
37. This function can crack the kind of password explained above. All
38. combinations
39. that are tried are displayed and when the password is found, #, is put
40. at the
41. start of the line. Note that one of the most time consuming operations
42. that
43. it performs is the output of intermediate results, so performance
44. experiments
45. for this kind of program should not include this. i.e. comment out the
46. printfs.
47. \*/

50. void function1(char \*salt\_and\_encrypted){
51. int x, y, z; // Loop counters
52. char salt[7]; // String used in hahttps://www.youtube.com/watch?v=L8yJjIGleMwshing the password. Need space
53. char plain[7]; // The combination of letters currently being checked
54. char \*enc; // Pointer to the encrypted password
55. int count = 0; // The number of combinations explored so far
57. substr(salt, salt\_and\_encrypted, 0, 6);
59. for(x='A'; x<='M'; x++){
60. for(y='A'; y<='Z'; y++){
61. for(z=0; z<=99; z++){
62. sprintf(plain, "%c%c%02d", x, y, z);
63. enc = (char \*) crypt(plain, salt);
64. count++;
65. if(strcmp(salt\_and\_encrypted, enc) == 0){
66. printf("#%-8d%s %s\n", count, plain, enc);
67. }
68. }
69. }
70. }
71. printf("%d solutions explored\n", count);
72. }
74. void function2(char \*salt\_and\_encrypted){
75. int i, j, k; // Loop counters
76. char salt[7]; // String used in hahttps://www.youtube.com/watch?v=L8yJjIGleMwshing the password. Need space
77. char plain[7]; // The combination of letters currently being checked
78. char \*enc; // Pointer to the encrypted password
79. int count = 0; // The number of combinations explored so far
81. substr(salt, salt\_and\_encrypted, 0, 6);
83. for(i='N'; i<='Z'; i++){
84. for(j='A'; j<='Z'; j++){
85. for(k=0; k<=99; k++){
86. sprintf(plain, "%c%c%02d", i,j,k);
87. enc = (char \*) crypt(plain, salt);
88. count++;
89. if(strcmp(salt\_and\_encrypted, enc) == 0){
90. printf("#%-8d%s %s\n", count, plain, enc);
91. }
92. }
93. }
94. }
95. printf("%d solutions explored\n", count);
96. }
98. //Calculating time
100. int time\_difference(struct timespec \*start, struct timespec \*finish, long long int \*difference)
101. {
102. long long int ds = finish->tv\_sec - start->tv\_sec;
103. long long int dn = finish->tv\_nsec - start->tv\_nsec;
105. if(dn < 0 ) {
106. ds--;
107. dn += 1000000000;
108. }
109. \*difference = ds \* 1000000000 + dn;
110. return !(\*difference > 0);
111. }
112. int main(int argc, char \*argv[])
113. {
115. struct timespec start, finish;
116. long long int time\_elapsed;
117. int size, rank, i;
118. clock\_gettime(CLOCK\_MONOTONIC, &start);
120. MPI\_Init(NULL, NULL);
121. MPI\_Comm\_size(MPI\_COMM\_WORLD, &size);
122. MPI\_Comm\_rank(MPI\_COMM\_WORLD, &rank);
123. if(size != 3) {
124. if(rank == 0) {
125. printf("This program needs to run on exactly 3 processes\n");
126. }
127. }
128. else{
129. if(rank == 0){
130. int x;
131. MPI\_Send(&x, 1, MPI\_INT, 1, 0, MPI\_COMM\_WORLD);
132. MPI\_Send(&x, 1, MPI\_INT, 2, 0, MPI\_COMM\_WORLD);
133. }
134. else if(rank == 1){
135. int number;
136. MPI\_Recv(&number, 1, MPI\_INT, 0, 0, MPI\_COMM\_WORLD,
137. MPI\_STATUS\_IGNORE);
138. for(i-0;i<n\_passwords;i<i++){
139. function1(encrypted\_passwords[i]);
140. }
141. }
142. else{
143. int number;
144. MPI\_Recv(&number, 1, MPI\_INT, 0, 0, MPI\_COMM\_WORLD,
145. MPI\_STATUS\_IGNORE);
146. for(i-0;i<n\_passwords;i<i++){
147. function2(encrypted\_passwords[i]);
148. }
149. }
150. }
152. MPI\_Finalize();
154. clock\_gettime(CLOCK\_MONOTONIC, &finish);
155. time\_difference(&start, &finish, &time\_elapsed);
156. if(rank==0){
157. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
158. (time\_elapsed/1.0e9));
159. }
160. return 0;
161. }

Code explanation

The above program in MPI uses two functions with 3 processes that assigns same amount of memory and run at the same time. The parameter uses in the above program is MPI send and MPI receive. MPI\_Send sends the exact count of elements, and MPI\_Recv will receive **at most** the count of elements. MPI\_send and MPI\_Recv has following parameters

MPI\_Send(&x (A pointer to the buffer that contains the data to be sent)

, 1 (The number of elements in the buffer. If the data part of the message is empty, set the count parameter to 0. ),

MPI\_INT (The data type of the elements in the buffer.),

1 (The rank of the destination process within the communicator that is specified by the comm parameter.),

0 (The message tag that can be used to distinguish different types of messages.),

MPI\_COMM\_WORLD (The handle to the communicator.));

And MPI\_Recv has one more parameter that is status [out].

MPI\_Comm\_rank and MPI\_Comm\_size are first used to determine the world size along with the rank of the process.

The communication in this is determined by MPI\_COMM\_WORLD that refers to the world size and the rank of the process.

MPI\_STATUS\_IGNORE is the only difference between MPI\_send and MPI\_recv, it is one extra argument in MPI\_recv that determines whether the value has been successfully passed or not.

MPI\_Finalize(): Terminates the calling MPI process’s execution environment.

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

A picture containing crossword puzzle

Description automatically generated

Figure 4 Table that shows running time of the original program

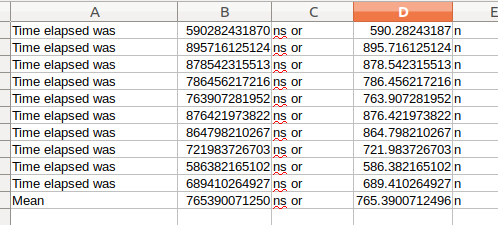


Figure 5 Table that shows running time of the MPI version

Write a short analysis of the results

Above table shows the mean running time of simple program and MPI version of Password cracking. The mean running time of simple program run is 678.42s and the MPI version is 765.39s. It is clear that the simple program of password cracking is faster than that of MPI version. In MPI program, message should be passed to different processor as a result it becomes over head which results in slow performance than the simple program.

## Image Processing

1. #include <stdio.h>
2. #include <stdlib.h>
3. #include <time.h>
4. #include <GL/glut.h>
5. #include <GL/gl.h>
6. #include <malloc.h>
7. #include <signal.h>
8. #include <mpi.h>
9. #include <unistd.h>
10. /\*
11. To compile:
12. mpicc -o image\_processing\_MPI image\_processing\_MPI.c -lglut -lGL -lm
14. To run:
15. mpirun -n 5 -quiet ./image\_processing\_MPI
16. \*/
18. #define width 100
19. #define height 72
21. unsigned char image[], results[width \* height];
22. int startIndex, endIndex;
23. void edges(unsigned char \*in, unsigned char \*out) {
24. int i;
25. int pixels = width \* height;
27. for(i=0;i<pixels;i++) {
28. int x, y; // the pixel of interest
29. int b, d, f, h; // the pixels adjacent to x,y used for the calculation
30. int r; // the result of calculate
32. y = i / width;
33. x = i - (width \* y);
35. if (x == 0 || y == 0 || x == width - 1 || y == height - 1) {
36. results[i] = 0;
37. } else {
38. b = i + width;
39. d = i - 1;
40. f = i + 1;
41. h = i - width;
43. r = (in[i] \* 4) + (in[b] \* -1) + (in[d] \* -1) + (in[f] \* -1)
44. + (in[h] \* -1);
46. if (r > 0) { // if the result is positive this is an edge pixel
47. out[i] = 255;
48. } else {
49. out[i] = 0;
50. }
51. }
52. }
53. }
55. void tidy\_and\_exit() {
56. exit(0);
57. }
59. void sigint\_callback(int signal\_number){
60. printf("\nInterrupt from keyboard\n");
61. tidy\_and\_exit();
62. }
64. static void show() {
65. glClear(GL\_COLOR\_BUFFER\_BIT);
66. glRasterPos4i(-1, -1, 0, 1);
67. glDrawPixels(width, height, GL\_LUMINANCE, GL\_UNSIGNED\_BYTE, image);
68. glRasterPos4i(0, -1, 0, 1);
69. glDrawPixels(width, height, GL\_LUMINANCE, GL\_UNSIGNED\_BYTE, results);
70. glFlush();
71. }
73. static void key\_pressed(unsigned char key, int x, int y) {
74. switch(key){
75. case 27: // escape
76. tidy\_and\_exit();
77. break;
78. default:
79. printf("\nPress escape to exit\n");
80. break;
81. }
82. }
83. int time\_difference(struct timespec \*start, struct timespec \*finish,
84. long long int \*difference) {
85. long long int ds = finish->tv\_sec - start->tv\_sec;
86. long long int dn = finish->tv\_nsec - start->tv\_nsec;
88. if(dn < 0 ) {
89. ds--;
90. dn += 1000000000;
91. }
92. \*difference = ds \* 1000000000 + dn;
93. return !(\*difference > 0);
94. }
96. int main(int argc, char \*\*argv) {
97. signal(SIGINT, sigint\_callback);
99. int size, rank;

102. MPI\_Init(NULL, NULL);
103. MPI\_Comm\_size(MPI\_COMM\_WORLD, &size);
104. MPI\_Comm\_rank(MPI\_COMM\_WORLD, &rank);
105. if(size != 5) {
106. if(rank == 0) {
107. printf("This program needs to run on exactly 5 processes\n");
108. }
109. }
110. else{
111. if(rank == 0) {
112. struct timespec start, finish;
113. long long int time\_elapsed;
115. clock\_gettime(CLOCK\_MONOTONIC, &start);
116. MPI\_Send(&results[0], 1800, MPI\_UNSIGNED\_CHAR, 1, 0, MPI\_COMM\_WORLD);
117. MPI\_Send(&results[1800], 1800, MPI\_UNSIGNED\_CHAR, 2, 0, MPI\_COMM\_WORLD);
118. MPI\_Send(&results[3600], 1800, MPI\_UNSIGNED\_CHAR, 3, 0, MPI\_COMM\_WORLD);
119. MPI\_Send(&results[5400], 1800, MPI\_UNSIGNED\_CHAR, 4, 0, MPI\_COMM\_WORLD);
121. MPI\_Recv(&results[0], 1800, MPI\_UNSIGNED\_CHAR, 1, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
122. MPI\_Recv(&results[1800], 1800, MPI\_UNSIGNED\_CHAR, 2, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
123. MPI\_Recv(&results[3600], 1800, MPI\_UNSIGNED\_CHAR, 3, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
124. MPI\_Recv(&results[5400], 1800, MPI\_UNSIGNED\_CHAR, 4, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
126. clock\_gettime(CLOCK\_MONOTONIC, &finish);
127. time\_difference(&start, &finish, &time\_elapsed);
128. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
129. (time\_elapsed/1.0e9));
131. glutInit(&argc, argv);
132. glutInitWindowSize(width \* 2,height);
133. glutInitDisplayMode(GLUT\_SINGLE | GLUT\_LUMINANCE);
135. glutCreateWindow("6CS005 Image Progessing Courework");
136. glutDisplayFunc(show);
137. glutKeyboardFunc(key\_pressed);
138. glClearColor(0.0, 1.0, 0.0, 1.0);
140. glutMainLoop();
142. tidy\_and\_exit();
143. }else{
144. if(rank==1){
145. startIndex=0;
146. endIndex=1799;
147. MPI\_Recv(&results[0], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
148. edges(image,results);
149. MPI\_Send(&results[0], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD);
150. }
151. else if(rank==2){
152. startIndex=1800;
153. endIndex=3599;
154. MPI\_Recv(&results[1800], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
155. edges(image,results);
156. MPI\_Send(&results[1800], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD);
157. }
158. else if(rank==3){
159. startIndex=3600;
160. endIndex=5399;
161. MPI\_Recv(&results[3600], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
162. edges(image,results);
163. MPI\_Send(&results[3600], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD);
164. }
165. else if(rank==4){
166. startIndex=5400;
167. endIndex=7199;
168. MPI\_Recv(&results[5400], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
169. edges(image,results);
170. MPI\_Send(&results[5400], 1800, MPI\_UNSIGNED\_CHAR, 0, 0, MPI\_COMM\_WORLD);
171. }
173. }
174. }
175. MPI\_Finalize();
176. return 0;
178. }

181. unsigned char image[] = {0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
182. 0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,
183. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
184. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
185. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
186. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
187. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
188. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
189. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,
190. 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,
192. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,
193. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
194. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
195. 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,
197. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
198. 0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
199. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
200. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
201. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
202. 0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
203. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
204. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
205. 255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,
206. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
207. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
208. 0,0,0,0,0,0,0,255,255,0,0,0,0,255,255,255,255,255,255,
209. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
210. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,
211. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
212. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
213. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,0,0,0,255,255,
214. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
215. 255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
216. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
217. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,0,0,
218. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,
219. 255,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
220. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,
221. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
222. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,
223. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
224. 0,255,255,0,255,255,255,0,0,255,255,255,255,255,255,255,255,255,255,
225. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
226. 255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
227. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
228. 0,0,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,
229. 0,0,0,0,255,255,255,255,255,255,255,255,255,0,0,255,255,255,255,
230. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
231. 255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
232. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
233. 0,0,0,0,0,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
234. 0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,0,
235. 0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
236. 255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,
237. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
238. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,0,
239. 0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,
240. 255,255,255,255,255,0,0,255,255,255,255,255,255,255,255,255,255,255,255,
241. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
242. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
243. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,
244. 255,255,255,255,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
245. 255,255,255,255,255,255,255,255,255,255,255,0,0,255,255,255,255,255,255,
246. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,
247. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
248. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,
249. 255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,255,
250. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,
251. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
252. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
253. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
254. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,
255. 0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
256. 255,255,255,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,
257. 255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
258. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
259. 0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
260. 0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,
261. 255,255,255,255,255,255,255,255,255,0,0,255,255,255,255,255,255,255,255,
262. 255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,
263. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
264. 0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,
265. 255,255,255,255,255,0,0,0,0,255,255,255,255,255,255,255,255,255,255,
266. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,255,255,
267. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,
268. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
269. 0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,
270. 255,255,255,255,255,255,255,255,255,255,0,0,0,255,255,255,255,255,255,
271. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
272. 255,255,0,0,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
273. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
274. 0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,
275. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,255,255,255,
276. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
277. 255,255,255,255,255,255,255,0,0,255,255,0,255,255,255,255,0,0,0,
278. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
279. 0,0,0,0,0,0,0,0,0,255,0,0,0,0,0,0,255,255,255,
280. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
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474. 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,
476. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,0,
477. 0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
478. 255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,
479. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
480. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
481. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,0,
482. 0,0,0,255,255,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
483. 255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,
484. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
485. 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,
487. 0,0,255,0,0,0,0,0,0,255,0,0,0,0,255,255,255,255,255,
488. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,
489. 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,
491. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
492. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,0,0,0,
493. 0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
494. 255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
495. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
496. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
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498. 0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,
499. 255,255,255,255,0,0,0,0,0,0,0,0,255,0,0,0,0,0,0,
500. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
501. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
502. 0,0,0,0,0,0,0,0,0,0,255,255,0,0,255,255,255,255,0,
503. 0,0,0,0,0,0,0,0,255,0,0,255,255,255,255,255,255,255,255,
504. 255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,
505. 0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
506. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
507. 0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,
508. 255,255,255,255,255,255,0,0,0,0,0,0,0,255,0,0,0,0,255,
509. 255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,
510. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
511. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
512. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,
513. 255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,
514. 0,0,0,0,0,255,255,255,255,255,255,255,255,255,0,0,0,0,0,
515. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
516. 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,
518. 0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,
519. 0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,0,0,
520. 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,
522. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
523. 0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
524. 255,255,255,255,255,255,0,0,0,0,0,0,0,0,0,0,0,255,255,
525. 255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
526. 0,0,0,0,0,0,255,0,0,0,0,0,0,0,255,0,0,0,0,
527. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
528. 0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,
529. 255,255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,
530. 0,0,255,255,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
531. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
532. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
533. 0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,
534. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,
535. 0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,
536. 0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
537. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
538. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,
539. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
540. 255,255,255,255,255,0,0,0,0,0,255,0,0,0,0,0,0,255,0,
541. 0,0,0,0,0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,
542. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
543. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
544. 0,0,0,0,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
545. 255,255,255,255,255,255,255,255,255,255,255,0,0,0,0,0,0,0,0,
546. 0,0,0,0,0,0,255,0,0,0,0,0,0,0,0,0,0,0,0,
547. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
548. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
549. 0,0,0,0,0,0,0,0,0,255,255,255,255,255,255,255,255,255,255,
550. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,0,255,
551. 0,0,0,0,0,0,0,0,0,0,0,255,255,0,0,0,0,0,0,
552. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
553. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
554. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,255,255,255,255,255,
555. 255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,
556. 255,255,255,255,0,0,0,0,0,0,0,0,0,0,255,0,0,0,0,
557. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
558. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
559. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
560. };

Code Explanation:

The above MPI program uses 4 processor in order to do the assigned task. The image is divided into 4 equal divisions of 1800 data in each process since the dimension of the image is 7200. Every data of the image is represented as the part of array since they are stored in array form. The MPI processes 1800 data starting form array [0] going on respectively to [1800], 93600], [5200]. The work is divided in 4 different processor using MPI\_Send and MPI\_Recv. The program results in two images one after applying the colour thresholding and the next after the edge detection

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

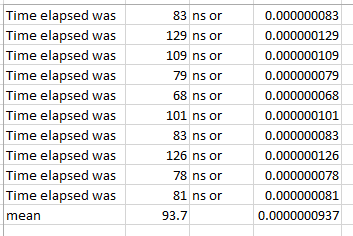


Figure 6 Running time of original program

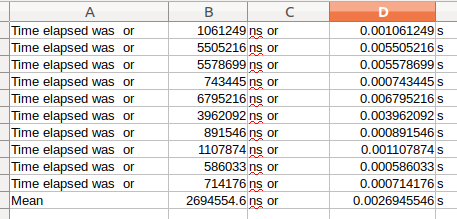


Figure 7 Running times for MPI version

Write a short analysis of the results.

The table above shows the mean running time of simple program and MPI program for image processing. The mean time for the original version was 93.7ns whereas the mean time for the MIP version is 2694554.6 ns. The difference between them is 2694460.9 ns. In this case we find that programmed executed with MPI is very slow than that of simple program. This happens because the data of image should be copped and passed to different memory location which make program overhead. In this program I have used 5 processor to send and receive the data. This process makes MPI program slower than original program.

## Linear Regression

1. #include <stdio.h>
2. #include <math.h>
3. #include <math.h>
4. #include <time.h>
5. #include <mpi.h>
6. #include <unistd.h>

9. /\*
10. To compile:
11. mpicc -o linearReg linearReg.c -lm
13. To run 9 processes on this computer:
14. mpirun -n 9 ./linearReg
15. \*/
16. typedef struct point\_t {
17. double x;
18. double y;
19. } point\_t;
21. int n\_data = 1000;
22. point\_t data[];
24. double residual\_error(double x, double y, double m, double c) {
25. double e = (m \* x) + c - y;
26. return e \* e;
27. }
29. double rms\_error(double m, double c) {
30. int i;
31. double mean;
32. double error\_sum = 0;
34. for(i=0; i<n\_data; i++) {
35. error\_sum += residual\_error(data[i].x, data[i].y, m, c);
36. }
38. mean = error\_sum / n\_data;
40. return sqrt(mean);
41. }
42. int time\_difference(struct timespec \*start, struct timespec \*finish, long long int \*difference)
43. {
44. long long int ds = finish->tv\_sec - start->tv\_sec;
45. long long int dn = finish->tv\_nsec - start->tv\_nsec;
47. if(dn < 0 ) {
48. ds--;
49. dn += 1000000000;
50. }
51. \*difference = ds \* 1000000000 + dn;
52. return !(\*difference > 0);
53. }
55. int main() {
57. struct timespec start, finish;
58. long long int time\_elapsed;
60. clock\_gettime(CLOCK\_MONOTONIC, &start);
62. int i;
63. double bm = 1.3;
64. double bc = 10;
65. double be;
66. double dm[8];
67. double dc[8];
68. double e[8];
69. double step = 0.01;
70. double best\_error = 999999999;
71. int best\_error\_i;
72. int minimum\_found = 0;
73. double pError=0;
74. double baseMC[2];
76. double om[] = {0,1,1, 1, 0,-1,-1,-1};
77. double oc[] = {1,1,0,-1,-1,-1, 0, 1};
78. int size, rank;

81. MPI\_Init(NULL, NULL);
82. MPI\_Comm\_size(MPI\_COMM\_WORLD, &size);
83. MPI\_Comm\_rank(MPI\_COMM\_WORLD, &rank);


87. be = rms\_error(bm, bc);
89. if(size!=9)
90. {
91. if(rank == 0) {
92. printf("This program needs to run on exactly 9 processes\n");
93. return 0;
94. }
95. }
96. while(!minimum\_found)
97. {
98. if (rank!=0)
99. {
101. i=rank-1;
102. dm[i] = bm + (om[i] \* step);
103. dc[i] = bc + (oc[i] \* step);
104. pError=rms\_error(dm[i], dc[i]);
106. MPI\_Send(&pError, 1, MPI\_DOUBLE, 0, 0, MPI\_COMM\_WORLD);
107. MPI\_Send(&dm[i], 1, MPI\_DOUBLE, 0, 0, MPI\_COMM\_WORLD);
108. MPI\_Send(&dc[i], 1, MPI\_DOUBLE, 0, 0, MPI\_COMM\_WORLD);


112. MPI\_Recv(&bm, 1, MPI\_DOUBLE, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
113. MPI\_Recv(&bc, 1, MPI\_DOUBLE, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
114. MPI\_Recv(&minimum\_found, 1, MPI\_INT, 0, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
115. }
116. else
117. {
118. for (i=1;i<size;i++){
119. MPI\_Recv(&pError, 1, MPI\_DOUBLE, i, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
120. MPI\_Recv(&dm[i-1], 1, MPI\_DOUBLE, i, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
121. MPI\_Recv(&dc[i-1], 1, MPI\_DOUBLE, i, 0, MPI\_COMM\_WORLD,MPI\_STATUS\_IGNORE);
122. if(pError < best\_error) {
123. best\_error=pError;
124. best\_error\_i=i-1;
125. }
126. }
127. if(best\_error < be) {
128. be = best\_error;
129. bm = dm[best\_error\_i];
130. bc = dc[best\_error\_i];
131. } else {
132. minimum\_found = 1;
133. }
134. for (i=1;i<size;i++){
135. MPI\_Send(&bm, 1, MPI\_DOUBLE, i, 0, MPI\_COMM\_WORLD);
136. MPI\_Send(&bc, 1, MPI\_DOUBLE, i, 0, MPI\_COMM\_WORLD);
137. MPI\_Send(&minimum\_found, 1, MPI\_INT, i, 0, MPI\_COMM\_WORLD);
138. }
139. }
140. }
142. if(rank==0){
144. printf("minimum m,c is %lf,%lf with error %lf\n", bm, bc, be);
145. clock\_gettime(CLOCK\_MONOTONIC, &finish);
146. time\_difference(&start, &finish, &time\_elapsed);
147. printf("Time elapsed was %lldns or %0.9lfs\n", time\_elapsed,
148. (time\_elapsed/1.0e9));
150. }
151. MPI\_Finalize();
152. return 0;
153. }


157. point\_t data[] = {
158. {72.12,100.78},{65.40,107.86},{82.27,131.60},{82.31,122.34},
159. {89.41,121.50},{71.37,113.51},{82.62,112.38},{69.57,102.96},
160. {65.38,99.27},{84.50,138.85},{87.18,114.17},{73.03,109.21},
161. {67.26,102.06},{72.25,113.23},{61.28,101.59},{41.60,84.24},
162. {40.14,57.03},{15.24,45.58},{61.88,89.90},{34.89,72.77},
163. { 8.91,36.34},{30.45,46.18},{67.93,89.35},{68.82,112.80},
164. {63.96,99.32},{32.36,56.12},{42.20,63.66},{24.47,60.75},
165. { 1.96,28.62},{41.42,68.41},{34.49,73.14},{ 8.03,22.13},
166. {80.55,117.79},{85.54,130.80},{68.99,103.13},{99.32,144.79},
167. {91.71,153.61},{71.17,108.40},{85.28,120.11},{99.52,128.68},
168. {13.24,31.67},{ 5.19,40.15},{ 9.84,57.36},{29.42,54.01},
169. {89.68,126.25},{29.45,41.30},{79.63,132.59},{71.88,107.31},
170. {20.05,48.38},{40.98,54.11},{56.55,63.61},{77.22,114.17},
171. {63.86,88.10},{92.93,134.84},{56.84,101.20},{34.31,71.18},
172. {93.89,116.43},{38.02,63.78},{61.25,94.71},{71.02,103.42},
173. {95.05,142.82},{96.24,133.50},{19.50,50.92},{41.14,70.59},
174. {91.49,134.05},{54.05,98.31},{36.59,68.48},{91.14,130.45},
175. {44.76,88.98},{77.28,138.16},{64.80,96.33},{43.25,70.08},
176. {55.55,95.70},{ 3.77,39.03},{ 3.23,44.69},{86.72,127.42},
177. {84.62,131.54},{26.13,71.24},{61.22,98.22},{53.90,96.07},
178. {64.81,109.35},{91.66,116.79},{53.65,104.81},{38.42,66.16},
179. {62.33,112.41},{ 7.41,29.86},{41.59,57.59},{56.49,91.60},
180. {15.94,42.82},{97.46,140.29},{57.17,85.11},{26.94,45.86},
181. {73.14,96.37},{18.61,60.58},{15.69,44.16},{20.79,33.86},
182. {65.02,106.03},{38.09,72.71},{87.15,116.68},{77.45,123.08},
183. {90.47,126.33},{26.80,44.96},{75.94,119.76},{33.83,69.11},
184. {63.59,103.98},{38.05,72.36},{68.28,110.76},{ 3.34,54.22},
185. {45.40,92.84},{78.37,113.49},{27.11,46.46},{32.32,68.44},
186. {20.97,30.90},{37.92,75.11},{96.85,130.96},{69.40,95.17},
187. { 3.29,30.06},{64.41,103.44},{15.80,52.64},{61.76,97.79},
188. { 1.62,33.98},{29.03,58.02},{18.74,34.93},{25.41,73.73},
189. {28.78,65.94},{14.64,50.31},{82.85,133.70},{41.62,90.32},
190. {99.28,144.95},{90.16,133.18},{40.45,77.72},{ 1.79,50.44},
191. {31.80,62.71},{26.30,40.89},{47.57,83.15},{17.78,44.90},
192. {69.48,93.13},{87.98,126.95},{69.84,106.00},{37.06,61.61},
193. {90.65,133.97},{10.73,46.60},{38.84,79.90},{ 4.75,33.89},
194. {48.99,89.31},{ 2.51,47.09},{34.99,86.40},{29.79,54.52},
195. {91.30,133.72},{74.12,122.86},{90.93,141.88},{51.14,89.93},
196. {84.53,142.49},{26.84,58.79},{ 6.95,20.98},{49.80,85.14},
197. {22.82,57.02},{44.08,89.32},{22.28,48.72},{21.12,50.68},
198. {65.69,93.93},{27.84,39.97},{ 1.92,40.39},{ 9.36,33.54},
199. {88.10,123.02},{18.15,63.84},{21.80,39.76},{64.42,101.03},
200. { 2.23,22.52},{55.68,99.56},{37.55,87.77},{74.23,104.87},
201. {11.96,37.30},{23.60,45.84},{11.13,34.32},{ 9.05,48.79},
202. {56.11,100.21},{19.31,54.44},{ 6.27,16.17},{64.65,101.39},
203. {50.25,77.59},{69.33,95.12},{47.52,87.79},{28.97,65.98},
204. {71.56,95.30},{19.71,41.47},{57.66,96.65},{41.07,74.10},
205. {35.08,79.46},{40.80,87.01},{ 0.31,19.82},{90.78,111.55},
206. {34.39,72.03},{99.97,139.40},{30.86,73.03},{14.37,50.15},
207. { 6.11,42.76},{21.75,80.30},{89.94,127.56},{10.86,42.40},
208. {13.07,42.98},{84.47,147.14},{83.44,132.18},{32.24,63.57},
209. {66.93,102.41},{34.48,68.96},{ 3.46,22.82},{94.84,130.83},
210. {49.41,107.26},{71.64,99.82},{47.28,80.62},{39.17,68.77},
211. {58.05,108.35},{69.27,109.81},{47.64,73.34},{34.64,73.15},
212. {22.86,46.34},{37.76,66.19},{ 3.12,39.11},{60.59,111.05},
213. {91.99,122.76},{96.60,138.86},{ 3.58,23.35},{22.81,60.18},
214. {13.93,21.32},{69.51,106.41},{19.57,43.39},{79.11,115.68},
215. {80.89,124.36},{44.42,57.78},{33.28,73.04},{21.45,49.88},
216. {70.57,113.77},{45.63,65.60},{55.99,72.21},{21.62,41.47},
217. {61.74,98.99},{ 9.30,29.77},{75.32,106.74},{27.97,73.44},
218. {74.77,115.98},{42.93,82.67},{92.32,138.05},{25.55,64.34},
219. { 0.48,23.51},{79.52,111.52},{52.83,70.58},{51.45,87.28},
220. {62.72,90.41},{ 4.16,40.60},{70.13,115.25},{55.96,97.34},
221. {93.88,154.09},{46.21,90.04},{34.75,51.46},{54.45,89.56},
222. {80.69,129.36},{45.14,73.00},{47.34,85.69},{70.16,118.02},
223. { 4.26,17.14},{61.56,98.04},{15.95,28.56},{74.06,118.48},
224. {65.29,99.71},{19.08,55.64},{37.82,72.36},{58.22,103.93},
225. {50.52,82.15},{26.25,60.91},{97.77,123.91},{39.13,68.03},
226. {15.09,41.88},{32.61,61.64},{11.23,22.85},{61.92,98.02},
227. {73.63,126.32},{35.12,54.74},{12.98,42.69},{83.87,128.60},
228. {45.65,78.81},{42.85,90.57},{76.74,117.53},{19.05,49.60},
229. {69.03,104.16},{23.66,54.97},{52.85,85.94},{82.07,128.27},
230. {74.77,111.22},{95.04,136.69},{40.49,49.53},{ 4.16,28.40},
231. { 7.69,51.29},{29.37,80.82},{86.06,122.19},{ 3.92,23.24},
232. {62.76,108.89},{27.12,54.24},{10.24,33.84},{79.86,107.97},
233. {57.09,85.27},{10.29,54.38},{53.50,82.98},{12.83,50.29},
234. { 2.09,13.69},{88.73,135.16},{42.72,87.10},{40.20,91.88},
235. {40.10,76.49},{80.22,133.65},{57.55,93.99},{29.34,69.08},
236. { 2.90,41.26},{44.60,82.03},{47.93,89.05},{98.17,123.11},
237. {17.21,45.91},{42.37,79.83},{90.89,119.42},{ 7.81,36.64},
238. {76.14,123.86},{47.79,83.40},{95.27,144.30},{44.13,98.20},
239. {19.97,37.36},{90.66,131.96},{75.41,117.80},{57.14,107.91},
240. {25.92,41.69},{90.86,130.36},{44.78,79.02},{23.00,29.10},
241. {91.67,118.13},{26.55,51.18},{41.60,74.91},{ 0.39, 6.79},
242. {86.31,102.08},{20.43,37.80},{ 5.39,28.65},{12.63,24.33},
243. {22.60,42.79},{ 1.77,14.54},{74.10,113.64},{54.46,87.67},
244. {18.64,49.32},{93.97,116.30},{42.62,87.04},{13.37,30.16},
245. {74.50,104.62},{18.28,67.85},{76.98,107.84},{25.89,57.35},
246. {13.52,42.87},{61.26,97.78},{ 5.97,31.34},{91.99,137.43},
247. {20.38,58.23},{ 9.59,31.56},{79.41,126.40},{89.90,134.36},
248. {73.18,111.44},{61.51,111.41},{99.96,147.82},{72.55,113.52},
249. {66.21,110.93},{36.47,59.41},{65.58,93.39},{24.93,51.71},
250. {58.00,95.89},{49.83,83.52},{53.35,89.98},{83.97,129.85},
251. {57.33,106.86},{53.94,98.13},{98.02,144.26},{47.28,72.52},
252. {45.48,100.70},{80.69,147.66},{96.14,140.01},{82.69,120.80},
253. {79.73,136.89},{11.42,27.51},{88.91,138.59},{25.53,51.26},
254. { 2.49,37.14},{63.89,93.28},{90.96,138.02},{15.27,53.03},
255. {25.39,51.31},{31.77,55.54},{88.25,124.46},{67.66,108.26},
256. {90.23,112.02},{17.40,43.85},{78.38,137.07},{96.28,149.45},
257. {77.38,120.54},{56.49,107.27},{99.00,141.67},{36.35,58.18},
258. {97.41,132.64},{15.03,48.28},{42.48,81.20},{62.95,105.32},
259. {99.76,147.11},{85.18,140.95},{99.23,131.84},{21.09,44.44},
260. {45.12,75.22},{80.36,119.71},{61.37,84.74},{82.64,128.58},
261. {70.34,108.16},{83.63,116.26},{47.73,67.57},{17.56,48.42},
262. {23.26,42.12},{41.81,82.17},{18.48,33.63},{39.11,70.14},
263. {84.20,123.97},{67.20,113.97},{52.74,87.79},{81.66,131.54},
264. {45.90,93.69},{20.82,34.77},{86.35,122.38},{78.93,106.82},
265. {10.56,44.66},{51.20,104.61},{93.79,131.97},{15.71,43.06},
266. {99.16,156.47},{90.70,135.27},{41.85,77.91},{73.41,106.66},
267. {57.51,108.55},{53.06,115.27},{25.72,67.45},{ 8.03,27.74},
268. {57.91,101.56},{35.87,57.47},{98.33,145.81},{50.96,76.84},
269. {57.86,102.10},{17.21,44.21},{95.62,154.59},{76.92,114.77},
270. {25.32,60.66},{43.60,68.34},{42.68,73.98},{60.36,84.81},
271. { 9.06,42.91},{ 4.16,18.44},{54.14,97.87},{ 4.87,35.92},
272. {75.38,112.62},{41.37,68.92},{88.16,163.96},{16.79,41.87},
273. { 9.77,40.62},{69.66,125.12},{70.35,118.66},{71.99,97.87},
274. {63.66,111.29},{ 2.01,19.46},{64.63,122.89},{48.39,84.19},
275. {28.15,64.69},{46.17,83.91},{25.12,45.94},{82.23,118.70},
276. {57.69,95.98},{24.42,62.91},{15.81,35.58},{75.28,106.87},
277. {95.74,133.25},{67.78,107.42},{80.89,128.72},{10.39,38.37},
278. {15.31,35.73},{61.45,110.46},{11.15,44.99},{30.80,63.26},
279. {84.29,122.39},{29.17,47.34},{80.68,138.44},{81.17,117.86},
280. { 8.47,32.78},{41.26,74.09},{43.50,71.18},{34.48,68.61},
281. {30.63,68.05},{88.63,137.28},{71.56,116.97},{21.03,39.12},
282. {88.20,116.24},{ 8.52,30.24},{95.79,137.27},{78.66,104.62},
283. {72.44,94.21},{71.60,106.34},{72.11,114.18},{34.50,59.18},
284. {22.85,60.95},{18.43,40.91},{69.24,119.69},{91.84,142.06},
285. {34.41,69.95},{95.06,136.92},{67.93,100.93},{46.96,71.82},
286. {63.92,102.14},{ 1.62,29.66},{95.24,133.60},{43.10,80.88},
287. {21.83,73.25},{35.01,62.42},{20.05,55.19},{18.64,45.92},
288. {40.28,75.26},{34.54,63.38},{84.74,117.68},{90.38,144.87},
289. { 9.91,24.87},{62.97,102.14},{34.40,79.20},{67.34,89.48},
290. {48.53,85.13},{24.57,51.59},{81.95,117.78},{22.23,49.77},
291. {75.86,125.20},{60.45,99.78},{19.93,35.57},{48.62,78.46},
292. {88.49,120.71},{13.33,40.67},{52.03,93.38},{38.43,80.28},
293. { 2.56,17.00},{18.39,58.10},{58.81,88.08},{75.76,96.69},
294. {69.78,98.83},{96.47,146.81},{47.32,79.89},{21.90,46.54},
295. {52.39,83.38},{75.49,107.96},{50.14,80.51},{41.54,73.80},
296. {76.07,117.48},{27.00,73.59},{81.59,122.88},{21.74,39.55},
297. {60.05,105.04},{75.68,102.72},{40.41,79.01},{ 0.32,24.82},
298. {50.06,106.14},{98.69,139.50},{64.17,109.26},{42.74,78.53},
299. {39.52,71.78},{55.14,97.37},{25.19,39.08},{99.31,142.63},
300. {67.50,91.86},{90.92,152.17},{81.99,129.38},{77.28,124.08},
301. {29.38,69.15},{ 3.81,41.93},{ 9.72,41.83},{25.75,53.09},
302. {57.28,85.11},{69.50,116.90},{20.00,51.46},{63.00,72.32},
303. {67.06,102.20},{37.85,64.86},{81.40,114.28},{13.32,58.41},
304. {67.21,103.77},{63.73,109.66},{91.43,141.66},{54.83,88.07},
305. {68.03,112.67},{ 0.51,27.76},{ 2.17,38.05},{36.26,66.58},
306. {72.67,116.52},{98.28,136.37},{85.27,128.64},{90.26,136.47},
307. {60.31,95.24},{32.77,58.94},{ 3.52,24.75},{15.98,45.49},
308. {94.25,145.90},{ 8.13,29.89},{61.13,81.38},{44.14,77.64},
309. {63.53,100.35},{49.35,97.92},{ 4.98,32.12},{25.53,57.45},
310. { 8.63,41.62},{24.23,56.27},{93.30,137.92},{43.72,71.72},
311. {54.15,89.12},{ 3.42,36.34},{57.75,85.68},{51.90,87.74},
312. {85.14,137.82},{99.27,173.87},{82.53,124.94},{15.38,44.42},
313. {66.66,108.56},{64.12,99.41},{39.08,73.77},{25.42,58.25},
314. { 1.29,36.39},{98.72,148.84},{70.09,112.06},{ 8.51,27.00},
315. {85.92,124.74},{88.32,127.04},{51.79,74.58},{36.46,62.45},
316. {49.29,85.33},{14.06,30.58},{24.83,34.82},{42.85,87.06},
317. {34.47,76.96},{59.16,90.44},{ 1.02,32.32},{61.80,108.22},
318. {72.52,95.83},{65.40,99.49},{53.32,93.79},{74.22,117.61},
319. {53.86,88.31},{39.84,80.11},{79.28,117.86},{34.57,76.73},
320. {21.69,55.55},{99.87,129.34},{72.12,108.86},{75.08,106.64},
321. {70.71,106.00},{18.35,67.45},{37.42,66.71},{ 0.70, 9.02},
322. {56.79,86.75},{74.04,100.45},{53.40,82.23},{42.13,70.45},
323. {82.43,123.55},{91.65,131.55},{94.99,153.70},{62.14,84.17},
324. {99.71,151.07},{33.24,73.77},{48.87,76.91},{68.57,118.95},
325. {14.28,46.22},{18.17,41.01},{95.93,133.32},{ 5.06,33.23},
326. {57.58,95.47},{18.71,39.10},{90.19,136.73},{26.98,50.08},
327. {11.36,26.14},{62.70,98.59},{49.32,80.54},{99.97,149.27},
328. {83.40,132.00},{25.30,48.62},{79.25,117.83},{81.09,109.23},
329. {31.46,51.02},{14.26,32.26},{33.53,52.63},{ 9.42,47.16},
330. {67.40,109.90},{18.56,32.79},{34.51,75.14},{49.00,77.38},
331. {15.69,50.80},{23.09,40.32},{32.03,67.86},{13.60,40.35},
332. {19.21,60.16},{78.56,111.57},{80.72,131.02},{50.19,79.64},
333. {55.60,81.78},{ 6.37,43.37},{42.78,74.85},{60.48,113.67},
334. {44.44,89.27},{54.02,90.24},{73.51,101.74},{16.41,56.73},
335. {70.94,104.90},{32.03,66.91},{13.12,49.71},{50.16,85.64},
336. {41.31,68.88},{69.25,123.25},{24.97,69.28},{40.80,86.30},
337. {32.28,67.01},{90.77,142.80},{66.77,104.70},{24.06,56.12},
338. {49.16,89.52},{46.10,95.56},{51.79,94.01},{56.11,100.66},
339. {88.49,126.71},{ 1.28,21.35},{35.55,64.10},{18.79,29.74},
340. { 5.40,40.02},{92.32,129.89},{21.13,47.05},{ 5.14,32.16},
341. {60.89,104.41},{43.45,76.07},{98.91,160.53},{99.31,155.80},
342. {74.71,121.53},{62.33,98.98},{58.66,101.10},{51.51,93.03},
343. {51.69,90.42},{19.47,31.22},{85.75,108.87},{64.20,100.48},
344. {96.60,142.66},{67.99,102.48},{68.37,120.07},{29.81,44.77},
345. {96.55,142.74},{30.59,43.25},{73.94,108.44},{49.77,88.88},
346. {59.48,98.21},{41.21,61.86},{38.63,83.41},{86.98,140.40},
347. {93.34,134.69},{87.92,119.52},{40.93,61.87},{ 2.43,30.68},
348. {50.74,71.81},{37.13,52.43},{ 1.50,22.18},{99.06,143.48},
349. { 1.67,27.67},{ 0.18,10.50},{54.13,77.05},{46.19,88.91},
350. {91.13,144.49},{ 8.95,28.33},{85.69,122.61},{50.30,95.60},
351. {48.63,103.49},{67.99,100.19},{69.21,112.13},{11.26,34.99},
352. {25.78,58.73},{84.35,112.36},{46.80,79.68},{69.54,117.99},
353. {40.30,74.33},{79.97,118.95},{23.28,55.71},{32.62,78.92},
354. {21.86,37.01},{ 5.07,22.57},{94.41,146.15},{40.14,60.81},
355. {95.80,125.35},{91.34,131.68},{72.55,113.56},{40.13,71.59},
356. {98.06,145.27},{90.55,144.08},{71.26,121.81},{33.85,71.13},
357. {85.74,142.63},{57.93,91.78},{ 7.63,39.30},{83.72,128.26},
358. {10.89,46.78},{39.79,66.98},{98.84,146.32},{84.62,123.91},
359. {23.16,31.94},{86.36,134.79},{44.19,63.74},{ 0.39,24.19},
360. {64.22,96.97},{66.47,103.78},{ 1.73,17.52},{22.25,36.77},
361. {31.88,59.39},{15.60,30.03},{16.08,41.91},{83.11,129.19},
362. {72.61,122.52},{19.02,41.06},{56.90,87.53},{65.85,97.02},
363. {81.40,120.35},{64.90,104.44},{73.35,119.00},{ 8.49,40.31},
364. {31.20,65.32},{28.29,75.05},{72.51,120.90},{20.42,48.84},
365. {71.46,111.59},{33.98,50.46},{72.48,111.29},{75.56,113.00},
366. {58.65,95.16},{23.66,44.95},{95.08,139.46},{80.12,115.20},
367. {67.77,101.97},{56.06,99.08},{99.03,138.47},{48.26,74.79},
368. {25.95,39.30},{85.20,137.70},{69.31,104.19},{86.19,122.91},
369. {37.99,87.47},{72.06,116.90},{ 5.66,28.92},{27.77,52.05},
370. {31.89,60.32},{18.01,48.92},{37.21,65.49},{73.76,107.20},
371. { 0.32,-0.71},{93.75,133.48},{69.11,109.63},{11.01,55.84},
372. {43.48,73.99},{20.76,57.44},{75.50,105.00},{98.74,150.46},
373. {40.75,90.93},{61.67,103.30},{93.48,155.96},{35.52,61.62},
374. {32.30,78.52},{28.92,49.61},{60.97,87.11},{13.59,47.58},
375. { 9.43,26.07},{58.00,107.90},{99.86,151.90},{34.01,57.82},
376. {39.02,59.14},{33.64,74.99},{ 2.28,20.21},{55.00,90.93},
377. {55.77,85.94},{79.17,134.03},{63.16,106.70},{17.58,32.28},
378. {24.29,34.68},{83.91,132.35},{96.44,129.86},{61.95,93.66},
379. {14.86,25.10},{15.53,33.29},{15.69,42.47},{80.60,126.11},
380. {16.01,46.33},{26.54,74.55},{ 2.67,37.10},{74.63,96.98},
381. {38.06,59.99},{56.59,96.87},{78.88,120.95},{87.56,121.75},
382. {73.54,119.27},{16.84,44.09},{44.24,89.36},{76.02,123.64},
383. {98.41,115.45},{12.11,48.19},{30.70,60.41},{55.51,100.49},
384. { 0.26,37.11},{83.43,124.44},{49.92,111.30},{65.55,99.48},
385. {77.61,119.44},{62.44,95.52},{21.80,61.06},{20.99,60.54},
386. {93.10,129.45},{54.96,91.05},{10.22,48.48},{66.77,108.83},
387. {40.83,87.14},{13.54,35.77},{31.44,62.92},{79.69,110.30},
388. {67.07,100.59},{28.81,78.71},{52.95,97.30},{39.89,81.67},
389. {58.79,75.89},{34.35,51.29},{38.03,64.97},{87.87,130.19},
390. {39.73,52.43},{ 1.64,31.22},{91.15,147.58},{54.08,101.10},
391. {53.53,74.54},{54.24,104.47},{15.04,51.28},{79.06,114.59},
392. {93.83,138.37},{94.89,122.18},{52.63,86.22},{27.83,68.05},
393. {54.51,94.07},{23.83,58.00},{86.88,141.66},{10.42,31.81},
394. {55.43,84.31},{45.04,85.30},{95.69,121.78},{17.28,35.32},
395. { 3.17,33.76},{51.61,69.81},{27.37,64.13},{88.92,160.98},
396. {31.40,64.46},{33.35,59.91},{82.48,128.89},{50.46,98.13},
397. {78.73,113.68},{70.08,115.27},{98.65,142.28},{ 9.15,50.95},
398. {16.74,35.73},{32.92,72.02},{ 1.29,18.94},{75.79,123.45},
399. {32.94,59.92},{61.72,81.50},{42.39,91.90},{70.15,108.81},
400. { 2.90,29.10},{59.68,87.41},{69.85,108.66},{71.21,107.81},
401. {24.09,46.47},{44.51,76.59},{ 7.30,34.83},{58.93,99.24},
402. { 1.24,22.60},{84.27,132.21},{54.11,87.19},{39.18,75.93},
403. {90.81,155.72},{67.68,88.19},{67.14,84.53},{53.98,86.47},
404. {67.28,106.68},{ 8.49,36.74},{34.96,62.55},{59.01,82.94},
405. {64.78,101.77},{66.24,110.82},{75.81,131.28},{62.82,76.02},
406. {73.95,116.37},{20.40,38.76},{45.06,84.65},{47.64,82.81},
407. {30.85,64.41},{77.10,112.67},{ 8.12,32.76},{39.56,53.41}
408. };

Code Explanation

The program presented on MPI runs on 8 processor to find the slope and the constant. To divide among the processor the program uses MPI\_Send and MPI\_Recv. These standards are done to transfer the task to the processor using the loop. The program uses the function moreover as normal C program. The difference in this program is the error is found inside the loop rather than creating the function to compare the error in between all the 1000 data.

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

![A screenshot of a cell phone

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDgRXhpZgAATU0AKgAAAAgABAE7AAIAAAAHAAAISodpAAQAAAABAAAIUpydAAEAAAAOAAAQyuocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAERpa2VzaAAAAAWQAwACAAAAFAAAEKCQBAACAAAAFAAAELSSkQACAAAAAzM2AACSkgACAAAAAzM2AADqHAAHAAAIDAAACJQAAAAAHOoAAAAIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Figure 8 Running time of simple program

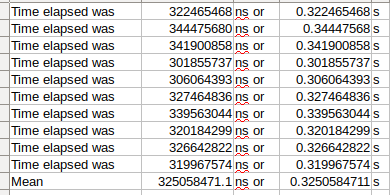


Figure 9 Running time of MPI version

Write a short analysis of the results.

The table above shows the mean running time of simple program and MPI version program for Linear regression. The mean time for the original version was 74.7ns whereas the mean time for the MPI version program is 325058471.1 ns. In this case we find that programmed executed with MIP version is slower than the simple program. Since MPI is built to run different process in different pc at the same time but in the program above the program us assigned with the 9 process because of which the program cannot be run properly and even the core is fewer which takes more time to plot the line which result to run the linear regression in MPI slower than the original version.

# 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