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Algorithms

Algorithm Steps for Computing the deepestConcavity given a peak starting point (x1, y1), a 1D histogram representation histAry, a slope m to the second peak point (x2, y2), the y-intercept b for that line, and a 2d-array displayGraph to store the results:

```
Max ← 0
First ← x1
Second ← x2
X ← First
Thr ← First
While X <= Second:
    Y ←m*X + b
    PlotOneRow(x, y, displayGraph)
    Gap ← | $histAry[x]- y$|
    If Gap > Max:
        Max ←Gap
        Thr ← X
    End-If
    X++
End-While-Loop
Return Thr
```

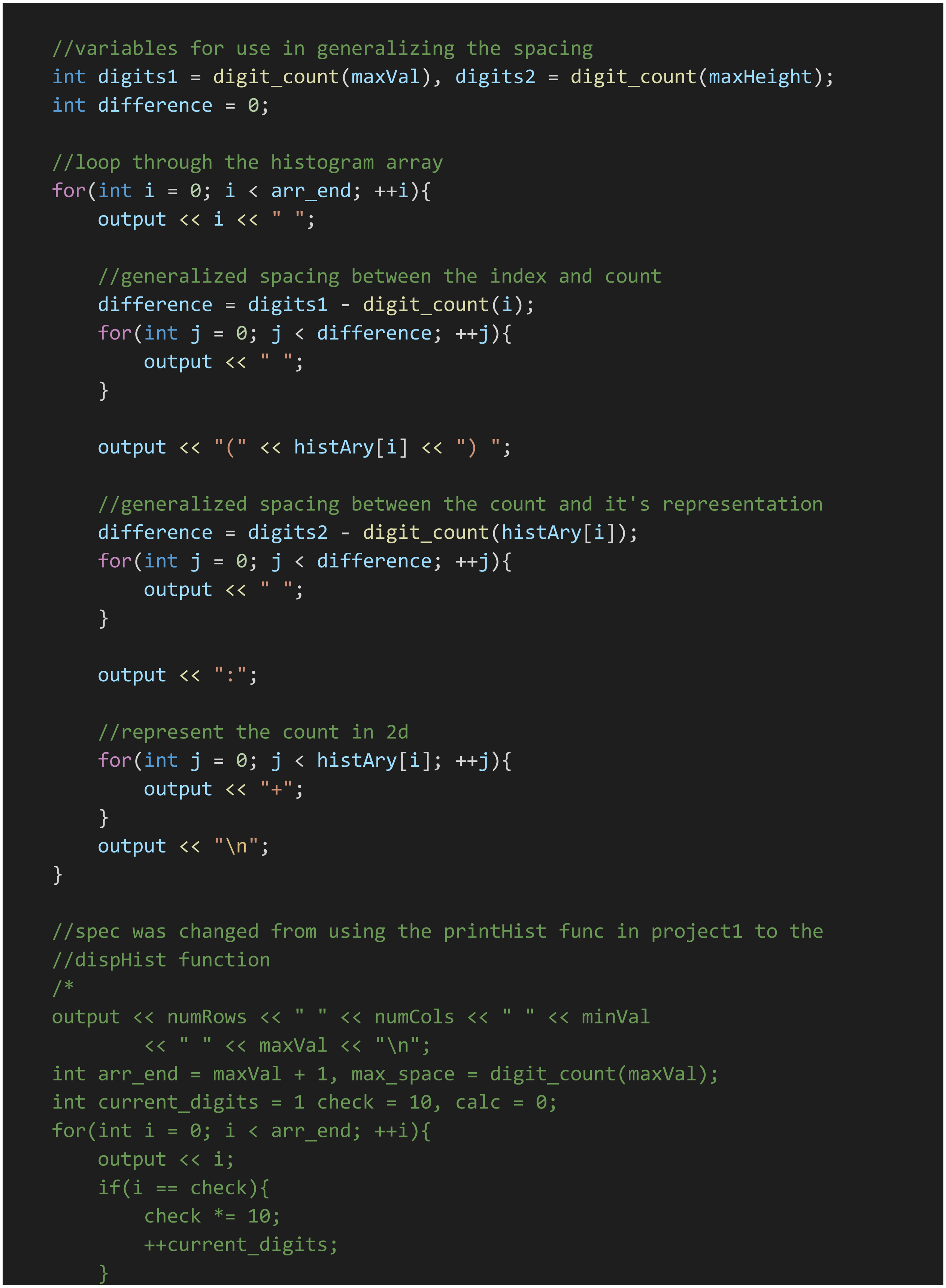
Algorithm Steps for PlotOneRow given an X value, Y value, and a 2D-array representation of the deepest concavity operations displayGraph, and a 1D array representation of a histogram histAry:

```
Index ← $\min(histAry[x], y)$
Last ← $\max(histAry[x], y)$
While Index <= Last:
    displayGraph[X][Index] ← 3
    Index++
End-While-Loop
displayGraph[X][histAry[X]] ← 1
displayGraph[X][Last] ← 2
```

Main.cpp

```
#include <iostream>
#include <fstream>

using namespace std;


class Concavity{
    public:
        //variables
        int numRows, numCols, maxVal, minVal; //image header specs
        int x1, y1, x2, y2; //histogram peaks
        double m, b; //the slope and y intercept of between the peaks
        int* histAry; //stores the histogram for the image
        int maxHeight; //max height found in histAry
        int bestThrVal; //auto selected threshold value
        int** displayGraph; //a graph representing our deepest concavity

        //constructor + destructor
        Concavity(int* points, ifstream& input);
        ~Concavity();

        //class functions
        int loadHist(ifstream& input); //returns the maxHeight
        void printHist(ofstream& output); //prints histogram to output file
        int deepestConcavity(); //returns a proposed threshold value
        void plotOneRow(int x, int y, int** display);
        void printGraph(ofstream& output); //print 2d graph after work is done
        int digit_count(int input); //counts digits in a number
};

int main(int argc, char** argv){


    //extract input and output files from command line arguments
    ifstream inFile1(argv[1]), inFile2(argv[2]);
    ofstream outFile1(argv[3]);

    //read in the first line of the points file where even indices are x's
    //and odd are y's
    int coords[4] = {0};
    for(int i = 0; i < 4; ++i){
        inFile2 >> coords[i];
    }
    //main algorithm, given a bimodal histogram and the peaks find the best
    //threshold value, graph everything, and output everything.
    Concavity concavity(coords, inFile1);
    concavity.printHist(outFile1);
    concavity.bestThrVal = concavity.deepestConcavity();
    outFile1 << "\nProposed best threshold value: " << concavity.bestThrVal;
    outFile1 << "\n";
    concavity.printGraph(outFile1);

    //close files
    inFile1.close();
    inFile2.close();
    outFile1.close();

    return 0;
}

//constructor, gives points of the peaks, calculates the slope and the
//intercept, calculates loads the histogram data and calculates the max
//histogram height. Initializes the displayGraph.
Concavity::Concavity(int* points, ifstream& input){

    //adds in points where index 2*i is x_(i+1) and index 2*i+1 is is y_(i+1)
    x1 = points[0];
    y1 = points[1];
    x2 = points[2];
    y2 = points[3];

    //find the slope of the line between points 1 and 2
    m = 1.0*(y2 - y1)/(x2 - x1);

    //finding the y-intercept, (y - y1) = m(x - x1) ->
    //y = m*x - m*x1 + y1 -> b = -m*x1 + y1
    b = 1.0*(-m*x1 + y1);

    //loads the histogram and finds the max value stored
    maxHeight = loadHist(input);

    //initializes a dynamic array to hold the display for deepest
    //concavity
    int max1 = maxVal+1, max2 = maxHeight+1;
    displayGraph = new int*[max1];
    for(int i = 0; i < max1; ++i){
        displayGraph[i] = new int[max2]();
    }
```

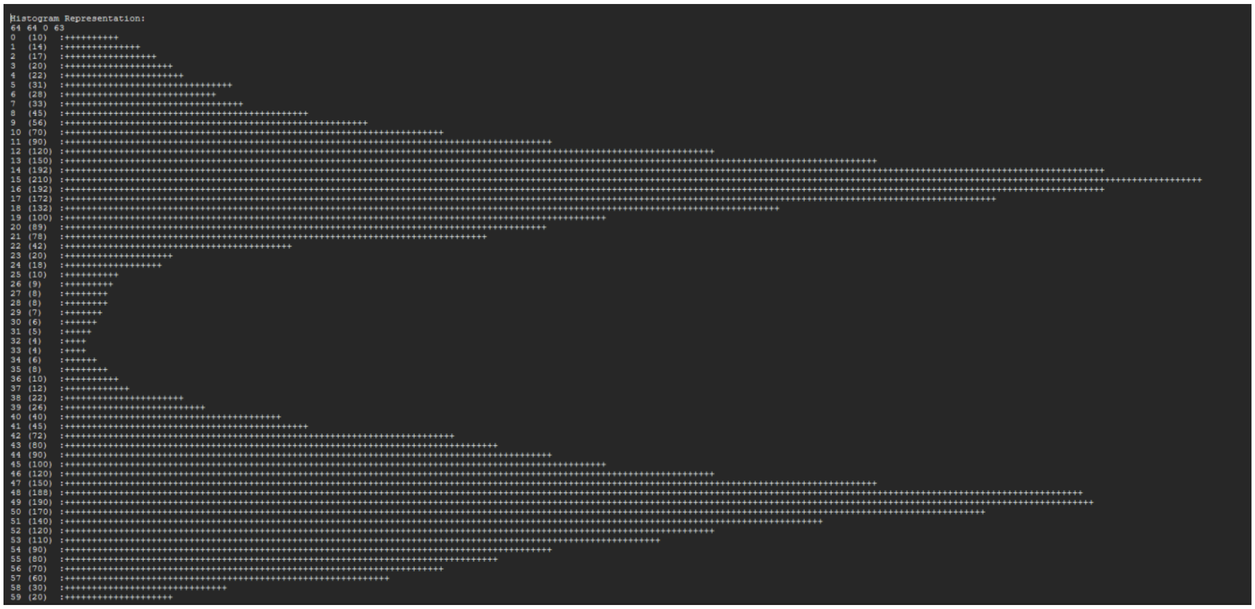
```
}

//deconstructor
Concavity::~Concavity(){

    //delete all dynamically allocated memory
    int max = maxVal+1;
    for(int i = 0; i < max; ++i){
        delete[] displayGraph[i];
    }
    delete[] displayGraph;
    delete[] histAry;
}

int Concavity::loadHist(ifstream& input){
    //load the first line / first four tokens which correspond to
    //this format
    input >> numRows;
    input >> numCols;
    input >> minVal;
    input >> maxVal;

    //allocate space for the array, initializing all to 0 and then
    //placing as we read
    histAry = new int[maxVal+1]();
    int index = 0, max = -1;
    for (int i = 0; i < maxVal; i++){
        input >> index;
        input >> histAry[index];

        //search for the max value stored in the histogram array
        if(histAry[i] > max) max = histAry[i];
    }

    //return the max value
    return max;
}

//print a visual 2d representation of the 1d histogram to a given file
void Concavity::printHist(ofstream& output){
    output << "Histogram Representation: \n";
    output << numRows << " " << numCols << " " << minVal
             << " " << maxVal << "\n";
    int arr_end = maxVal + 1;
```



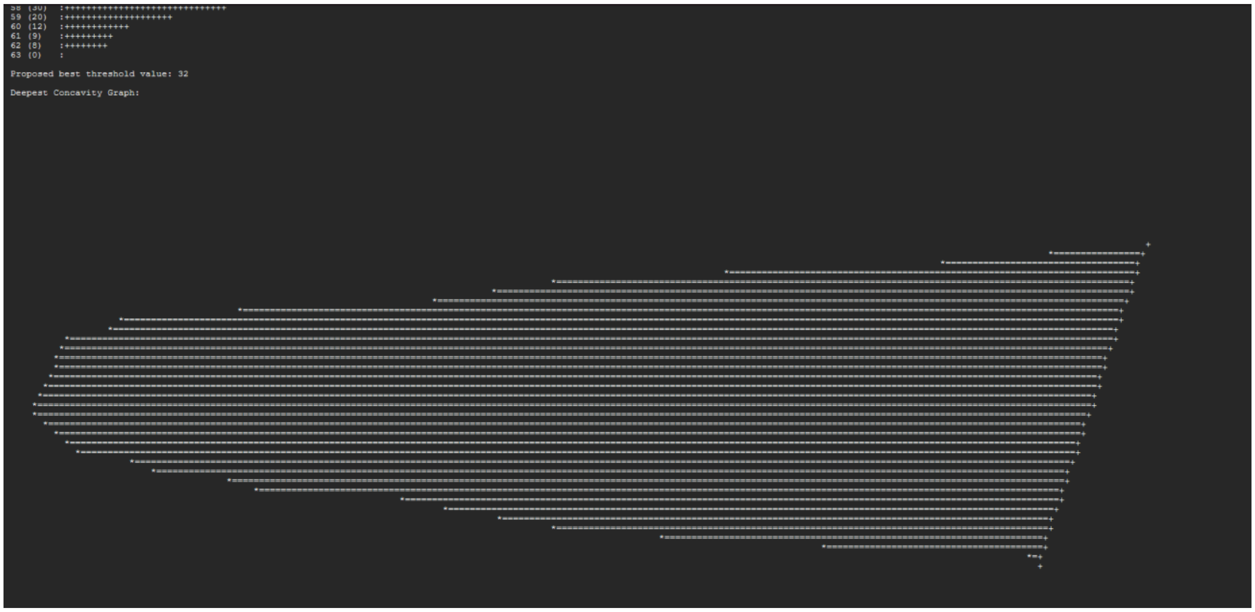
```cpp
//variables for use in generalizing the spacing
int digits1 = digit_count(maxVal), digits2 = digit_count(maxHeight);
int difference = 0;

//loop through the histogram array
for(int i = 0; i < arr_end; ++i){
    output << i << " ";

    //generalized spacing between the index and count
    difference = digits1 - digit_count(i);
    for(int j = 0; j < difference; ++j){
        output << " ";
    }

    output << "(" << histAry[i] << ") ";

    //generalized spacing between the count and it's representation
    difference = digits2 - digit_count(histAry[i]);
    for(int j = 0; j < difference; ++j){
        output << " ";
    }

    output << ":";

    //represent the count in 2d
    for(int j = 0; j < histAry[i]; ++j){
        output << "+";
    }
    output << "\n";
}

//spec was changed from using the printHist func in project1 to the
//dispHist function
/*
output << numRows << " " << numCols << " " << minVal
        << " " << maxVal << "\n";
int arr_end = maxVal + 1, max_space = digit_count(maxVal);
int current_digits = 1 check = 10, calc = 0;
for(int i = 0; i < arr_end; ++i){
    output << i;
    if(i == check){
        check *= 10;
        ++current_digits;
    }
```

```
        calc = max_space - current_digits + 1;
        for(int j = 0; j < calc; ++j){
            output << " ";
        }
        output << histAry[i] << "\n";
    }
    */
}

//plots the concavity chart, finds the largest gap between line and
//histogram value, and returns thex value for that spot
int Concavity::deepestConcavity(){
    //initialize variables
    int max = 0, first = x1, second = x2, x = first, y, thr = first, gap = 0;

    //climb the line from peak to peak starting at the first peak
    //and calculate the distance to the histogram value at the spot
    while(x <= second){
        y = (int)(m*x+b);
        //plots the information in the 2d representation of deepest
        //concavity calculation
        plotOneRow(x, y, displayGraph);

        //gap = |hist[x] - y| without the use of another library
        gap = (histAry[x] > y) ? histAry[x] - y : y - histAry[x];

        //keep track of the largest gap found between histogram values
        //and the line
        if (gap > max){
            max = gap;
            thr = x;
        }
        ++x;
    }
    return thr;
}

//adds one row to the 2d dynamic array representing the deepest concavity
//calculation
void Concavity::plotOneRow(int x, int y, int** display){

    //determine if the line is above or below the current histogram value
    int index = (histAry[x] < y) ? histAry[x] : y;
    int last = (histAry[x] > y) ? histAry[x] : y;
    //record the space between the values in the 2d representation
    while(index <= last){
        displayGraph[x][index] = 3;
        ++index;
    }

    //record where the histogram and line points are for this row in the 2d
    //representation
    displayGraph[x][histAry[x]] = 1;
    displayGraph[x][last] = 2;
}

//prints a 2d graph representing the deepest concavity calculation to a given
//output file
void Concavity::printGraph(ofstream& output){
    //initialize variables and label graph
    int max1 = maxVal+1, max2 = maxHeight+1;
    output << "\nDeepest Concavity Graph: \n";

    //print the graph to the output file row by row with different values
    //depending on the points relation to the deepest concavity calculation
    for(int i = 0; i < max1; ++i){
        for(int j = 0; j < max2; ++j){
            if(displayGraph[i][j] == 0) output << " ";
            else if(displayGraph[i][j] == 1) output << "*";
            else if(displayGraph[i][j] == 2) output << "+";
            else output << "=";
        }
        output << "\n";
    }
}

//helper function that counts the amount of digits in a number
//used to generalize spacing for prettier outputs
int Concavity::digit_count(int input){
    int num_digits = 0, temp = input;
    while(temp > 0){
        num_digits++;
        temp /= 10;
    }

    //if num_digits is 0 then we were given a 0, which has 1 digit
    if(num_digits == 0) return 1;
    return num_digits;
}
```

Output for data1

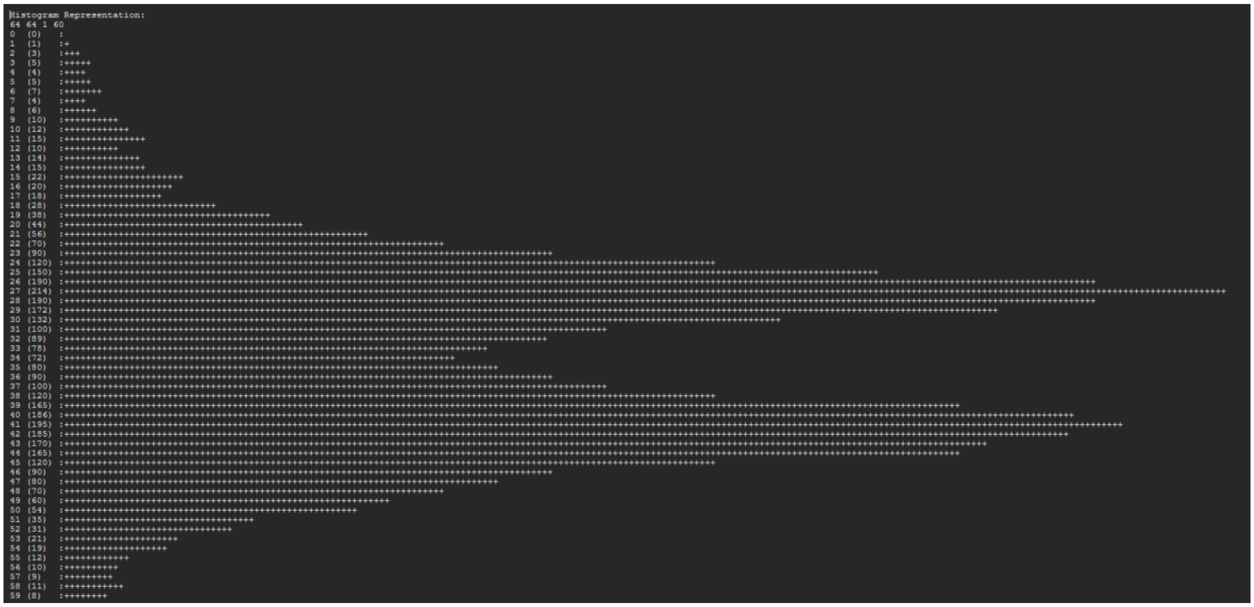


```
Histogram Representation:
64 64 0 63
0  (10)  :++++++++++
1  (14)  :++++++++++++++
2  (17)  :+++++++++++++++++
3  (20)  :++++++++++++++++++++
4  (22)  :++++++++++++++++++++++
5  (31)  :+++++++++++++++++++++++++++++++
6  (28)  :++++++++++++++++++++++++++++
7  (33)  :+++++++++++++++++++++++++++++++++
8  (45)  :+++++++++++++++++++++++++++++++++++++++++++++
9  (56)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++
10 (70)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
11 (90)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12 (120) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
13 (150) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
14 (192) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
15 (210) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
16 (192) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
17 (172) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
18 (132) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
19 (100) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
20 (89)  :+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
21 (78)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
22 (42)  :++++++++++++++++++++++++++++++++++++++++++
23 (20)  :++++++++++++++++++++
24 (18)  :++++++++++++++++++
25 (10)  :++++++++++
26 (9)   :+++++++++
27 (8)   :++++++++
28 (8)   :++++++++
29 (7)   :+++++++
30 (6)   :++++++
31 (5)   :+++++
32 (4)   :++++
33 (4)   :++++
34 (6)   :++++++
35 (8)   :++++++++
36 (10)  :++++++++++
37 (12)  :++++++++++++
38 (22)  :++++++++++++++++++++++
39 (26)  :++++++++++++++++++++++++++
40 (40)  :++++++++++++++++++++++++++++++++++++++++
41 (45)  :+++++++++++++++++++++++++++++++++++++++++++++
42 (72)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
43 (80)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
44 (90)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
45 (100) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
46 (120) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
47 (150) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
48 (188) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
49 (190) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
50 (170) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
51 (140) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
52 (120) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
53 (110) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
54 (90)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
55 (80)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
56 (70)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
57 (60)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
58 (30)  :++++++++++++++++++++++++++++++
59 (20)  :++++++++++++++++++++
```

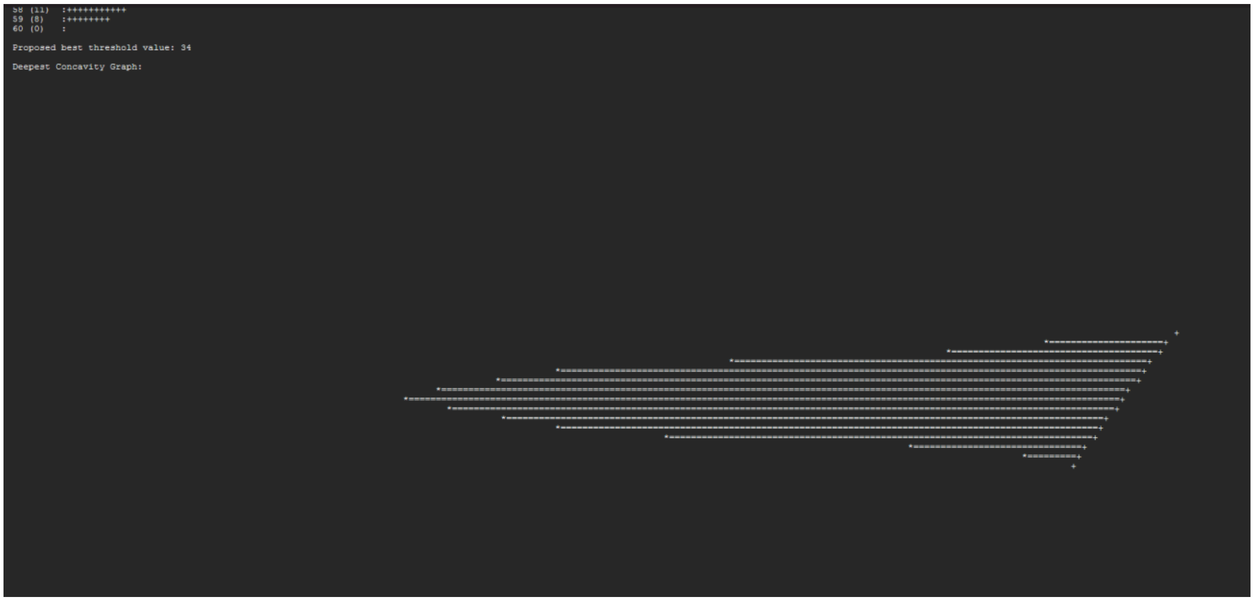


```
58 (30)  :++++++++++++++++++++++++++++++
59 (20)  :++++++++++++++++++++
60 (12)  :++++++++++++
61 (9)   :+++++++++
62 (8)   :++++++++
63 (0)   :

Proposed best threshold value: 32

Deepest Concavity Graph:
```

Output for Data2



```
Histogram Representation:
64 64 1 60
0  (0)   :
1  (1)   :+
2  (3)   :+++
3  (5)   :+++++
4  (4)   :++++
5  (5)   :+++++
6  (7)   :+++++++
7  (4)   :++++
8  (6)   :++++++
9  (10)  :++++++++++
10 (12)  :++++++++++++
11 (15)  :+++++++++++++++
12 (10)  :++++++++++
13 (14)  :++++++++++++++
14 (15)  :+++++++++++++++
15 (22)  :++++++++++++++++++++++
16 (20)  :++++++++++++++++++++
17 (18)  :++++++++++++++++++
18 (28)  :++++++++++++++++++++++++++++
19 (38)  :++++++++++++++++++++++++++++++++++++++
20 (44)  :++++++++++++++++++++++++++++++++++++++++++++
21 (56)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++
22 (70)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
23 (90)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
24 (120) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
25 (150) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
26 (190) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
27 (214) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
28 (190) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
29 (172) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
30 (132) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
31 (100) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
32 (89)  :+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
33 (78)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
34 (72)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
35 (80)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
36 (90)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
37 (100) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
38 (120) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
39 (165) :+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
40 (186) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
41 (195) :+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
42 (185) :+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
43 (170) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
44 (165) :+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
45 (120) :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
46 (90)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
47 (80)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
48 (70)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
49 (60)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
50 (54)  :++++++++++++++++++++++++++++++++++++++++++++++++++++++
51 (35)  :+++++++++++++++++++++++++++++++++++
52 (31)  :+++++++++++++++++++++++++++++++
53 (21)  :+++++++++++++++++++++
54 (19)  :+++++++++++++++++++
55 (12)  :++++++++++++
56 (10)  :++++++++++
57 (9)   :+++++++++
58 (11)  :+++++++++++
59 (8)   :++++++++
```



```
58 (11)  :+++++++++++
59 (8)   :++++++++
60 (0)   :

Proposed best threshold value: 34

Deepest Concavity Graph:
```