```
Computer Vision
   1 Project 5: 1 Image 1
Compression via Distance
1 2 2 3 2 2Transform
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        3/28/2021
```

Algorithms steps for Image Compression via Distance Transform

Distance transform Algorithm

Pass 1

- 1. Scan given image left to right and top to bottom.
- 2. If the current pixel is greater than 0. Look at current pixels surrounding neighbors.
- 3. Apply the given template and find the minimum of each neighbor.
- 4. Repeat until all pixels are processed.

Pass 2

- 1. Scan given image right to left and bottom to top.
- 2. If the current pixel is greater than 0. Look at all neighbors.
- 3. Calculate the min of each neighbor including the current pixel and apply the given template.

Local Maxima Operation

- 1. Scan given image left to right and top to bottom.
- 2. Check if current pixel is a local maximum.
 - a. Scan each neighbor and if they are lesser than the current pixel replaces the current pixels value with 0.
 - b. However, if they are greater than or equal write the pixel to the skeleton array.

Skeleton Image Compression

- 1. Using the Local Maxima Operation. Scan the image left to right and top the bottom.
 Results of Lossless compression
- 2. If the current pixel is greater than 0.
- 3. Display the row, col, and value.

30 40 0 1 2 11 1 4 11 2 5 27 5

Expansion Pass 1

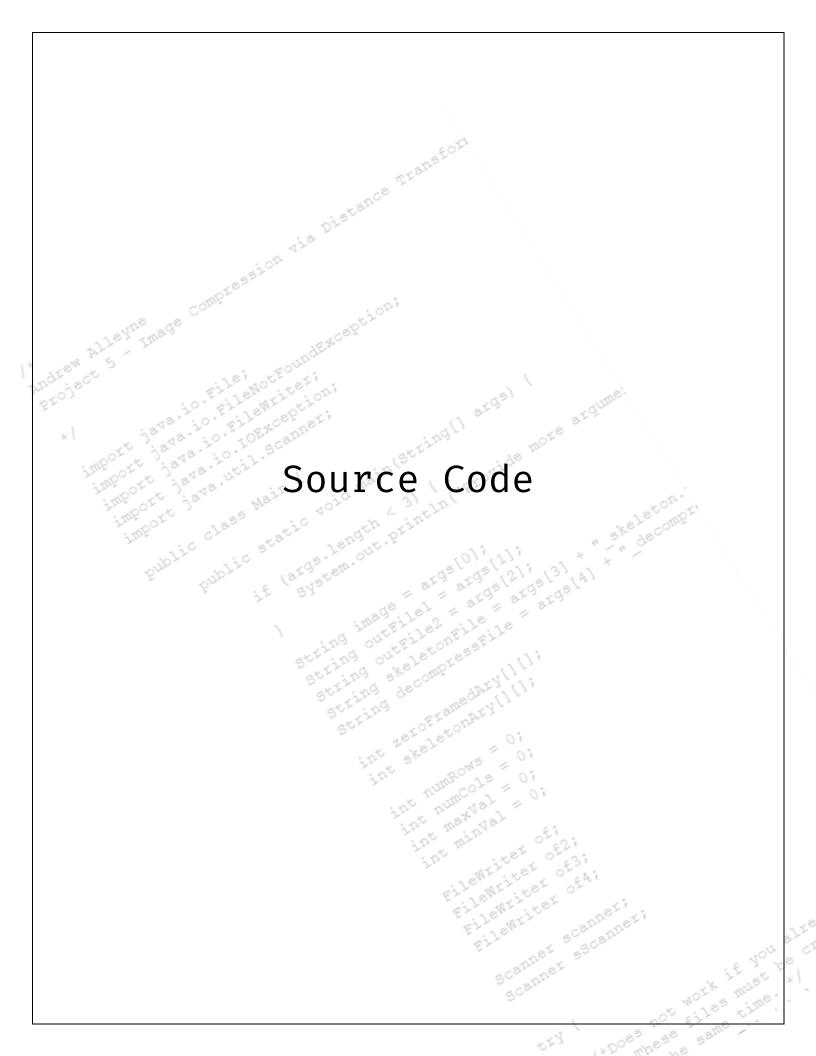
- 1. Scan given image left to right and top to bottom.
- 2. If the current pixel is equal to 0. Look at current pixels surrounding neighbors.
- 3. Calculate the max of each neighbor using the current pixel and apply the given template.
- 4. Repeat these steps until all pixels are processed.

Expansion Pass 2

- 1. Scan given image left to right and top to bottom.
- 2. Look at neighbors of the current pixel.
- 3. Calculate the max of each neighbor using the current pixel and apply the given template.
- 4. If the max is found for the given neighbors, current Pixel = max 1.
- 5. Repeat these steps until all pixels are processed.







Driver Code

```
Andrew Alleyne
Project 5 - Image Compression via Distance Transform
* /
import java.io.File;
import java.io.FileNotFoundException;
import java.io.FileWriter;
import java.io.IOException;
import java.util.Scanner;
public class Main {
   public static void main(String[] args) {
        if (args.length < 3) {</pre>
            System.out.println("Provide more arguments");
        String image = args[0];
        String outFile1 = args[1];
        String outFile2 = args[2];
        String skeletonFile = args[3] + " skeleton.txt";
        String decompressFile = args[4] + " decompressed.txt";
        int zeroFramedAry[][];
        int skeletonAry[][];
        int numRows = 0;
        int numCols = 0;
        int maxVal = 0;
        int minVal = 0;
        FileWriter of;
        FileWriter of2;
        FileWriter of3;
        FileWriter of4;
        Scanner scanner;
        Scanner sScanner;
        try {
            /*Does not work if you already have a named file in your
directory. These files must be created
            * at the same time. */
            File sf = new File(skeletonFile);
            File df = new File(decompressFile);
            if (sf.createNewFile() && df.createNewFile()) {
                System.out.println(sf.getName() + " has been created!");
```

```
System.out.println(df.getName() + " has been created!");
            } else {
                System.out.println(sf.getName() + " may already exist!");
                System.out.println(df.getName() + " may already exist!");
            }
            File file = new File(image);
            File sFile = new File(skeletonFile);
            scanner = new Scanner(file);
            sScanner = new Scanner(sFile);
            if (scanner.hasNextInt()) numRows = scanner.nextInt();
            if (scanner.hasNextInt()) numCols = scanner.nextInt();
            if (scanner.hasNextInt()) minVal = scanner.nextInt();
            if (scanner.hasNextInt()) maxVal = scanner.nextInt();
            of = new FileWriter(outFile1);
            of2 = new FileWriter(outFile2);
            of3 = new FileWriter(skeletonFile);
            of4 = new FileWriter(decompressFile);
            zeroFramedAry = new int[numRows + 2][numCols + 2];
            skeletonAry = new int[numRows + 2][numCols + 2];
            imageProcessing ip = new imageProcessing(numRows, numCols,
minVal, maxVal);
            //Zero frame array to preform operations on binary image
            ip.setZero(zeroFramedAry);
            ip.setZero(skeletonAry);
            ip.loadImage(scanner, zeroFramedAry);
            ip.compute8DistancePass1(zeroFramedAry, of);
            ip.reformatPrettyPrint(zeroFramedAry, of);
            ip.compute8DistancePass2(zeroFramedAry, of);
            ip.reformatPrettyPrint(zeroFramedAry, of);
            ip.skeletonExtraction(zeroFramedAry, skeletonAry, of);
            ip.reformatPrettyPrint(skeletonAry, of);
            ip.extractLocalMaxima(skeletonAry, of3);
            ip.setZero(zeroFramedAry);
            ip.load(sScanner, zeroFramedAry);
            ip.skeletonExpansionPass1(zeroFramedAry, of2);
            ip.reformatPrettyPrint(zeroFramedAry, of2);
```

```
ip.skeletonExpansionPass2(zeroFramedAry, of2);
            ip.reformatPrettyPrint(zeroFramedAry, of2);
            //ary2File (zeroFramedAry, decompressFile)
            ip.thresholdDecompression(zeroFramedAry, of4);
            of.close();
            of2.close();
            of3.close();
            of4.close();
        } catch (FileNotFoundException e) {
            System.out.println("Could not find the specified file!");
            e.printStackTrace();
        } catch (IOException e) {
            System.out.println("Failed I/O operation!");
            e.printStackTrace();
        }
   }
}
```

```
Image Processing Class
```

```
import java.io.FileWriter;
import java.io.IOException;
import java.util.Scanner;
public class imageProcessing {
    int numRows;
    int numCols;
    int maxVal;
    int minVal;
    int newMinVal;
    int newMaxVal;
    int neigh[];
    imageProcessing(int numRows, int numCols, int minVal, int maxVal) {
        this.numRows = numRows;
        this.numCols = numCols;
        this.minVal = minVal;
        this.maxVal = maxVal;
        neigh = new int[10];
    }
    void setZero(int array[][]) {
        for (int i = 0; i < numRows + 2; i++) {
            for (int j = 0; j < numCols + 2; j++) {
                array[i][j] = 0;
        }
    }
    void loadImage (Scanner scanner, int zeroFramedAry[][]) {
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j <= numCols; j++) {</pre>
                if (scanner.hasNextInt()) zeroFramedAry[i][j] =
scanner.nextInt();
            }
        }
    }
    void reformatPrettyPrint (int array[][], FileWriter of) throws IOException
{
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j <= numCols; j++) {</pre>
                int number = array[i][j];
                if (number == 0) {
                     of.write(" ");
                 } else {
```

```
of.write(number + " ");
                }
            of.write("\n");
        }
        of.flush();
        of.write("\n");
    }
    void compute8DistancePass1 (int zeroFramedAry[][], FileWriter of) throws
IOException {
        of.write("Results of 1st Distance Transform Pass: \n");
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j <= numCols; j++) {</pre>
                if (zeroFramedAry[i][j] > 0) {
                    zeroFramedAry[i][j] = neighborMin(zeroFramedAry, i, j,
1);
                }
            }
        of.flush();
    }
    void compute8DistancePass2 (int zeroFramedAry[][], FileWriter of) throws
IOException {
        of.write("Results of 2nd Distance Transform Pass: \n");
        for (int i = numRows; i >= 1; i--) {
            for (int j = numCols; j \ge 1; j--) {
                if (zeroFramedAry[i][j] > 0) {
                    zeroFramedAry[i][j] = neighborMin(zeroFramedAry, i, j,
2);
                }
            }
        }
        of.flush();
    }
    int neighborMin(int zeroFramedAry[][], int i, int j, int pass) {
        int firstMin = 0;
        if (pass == 1) {
            neigh[0] = zeroFramedAry[i - 1][j - 1] + 1;
            neigh[1] = zeroFramedAry[i - 1][j] + 1;
            neigh[2] = zeroFramedAry[i - 1][j + 1] + 1;
            neigh[3] = zeroFramedAry[i][j - 1] + 1;
            firstMin = neigh[0];
            for (int k = 0; k < 4; k++) {
                if (firstMin > neigh[k]) {
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```
firstMin = neigh[k];
                }
            }
        }
        if (pass == 2) {
            neigh[0] = zeroFramedAry[i + 1][j - 1] + 1;
            neigh[1] = zeroFramedAry[i + 1][j] + 1;
            neigh[2] = zeroFramedAry[i + 1][j + 1] + 1;
            neigh[3] = zeroFramedAry[i][j + 1] + 1;
            neigh[4] = zeroFramedAry[i][j];
            firstMin = neigh[0];
            for (int k = 0; k \le 4; k++) {
                if (firstMin > neigh[k]) firstMin = neigh[k];
        }
        return firstMin;
    }
    void skeletonExtraction(int zeroFramedAry[][], int skeletonAry[][],
FileWriter of) throws IOException {
        of.write("Results of Local Maxima: \n");
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j <= numCols; j++) {</pre>
                if (zeroFramedAry[i][j] > 0) {
                    computeLocalMaxima(zeroFramedAry, skeletonAry, i, j);
                }
            }
        }
        of.flush();
    }
    void computeLocalMaxima(int zeroFramedAry[][], int skeletonAry[][], int
i, int j) {
        neigh[0] = zeroFramedAry[i - 1][j - 1];
        neigh[1] = zeroFramedAry[i - 1][j];
        neigh[2] = zeroFramedAry[i - 1][j + 1];
        neigh[3] = zeroFramedAry[i][j - 1];
        neigh[4] = zeroFramedAry[i][j + 1];
        neigh[5] = zeroFramedAry[i + 1][j - 1];
        neigh[6] = zeroFramedAry[i + 1][j];
        neigh[7] = zeroFramedAry[i + 1][j + 1];
        int max = 0;
        for (int k = 0; k < 8; k++) {
            if (zeroFramedAry[i][j] >= neigh[k]) {
                max = zeroFramedAry[i][j];
```

```
} else {
                max = 0;
                break;
            }
        skeletonAry[i][j] = max;
   void extractLocalMaxima(int skeletonAry[][], FileWriter of3) {
        try {
            of3.write("Results of Lossless compression: \n \n");
            of3.write(numRows + " " + numCols + " " + minVal + " " + maxVal +
"\n");
            of3.write("\n");
            int max = skeletonAry[0][0];
            for (int i = 1; i <= numRows; i++) {</pre>
                for (int j = 1; j <= numCols; j++) {</pre>
                    if (skeletonAry[i][j] > 0) {
                        of3.write((i) + " " + (j) + " " + skeletonAry[i][j] +
"\n");
                        if (skeletonAry[i][j] > max) {
                            max = skeletonAry[i][j];
                        }
                    }
                }
            }
            newMaxVal = max;
            of3.flush();
        } catch (IOException e) {
            System.out.println("Could not extract local maxima!");
            e.printStackTrace();
       }
    }
   void load(Scanner sScanner, int zeroFramedAry[][]) {
        if (sScanner.hasNextLine()) {
            sScanner.nextLine();
        }
        if (sScanner.hasNextInt()) numRows = sScanner.nextInt();
        if (sScanner.hasNextInt()) numCols = sScanner.nextInt();
        if (sScanner.hasNextInt()) minVal = sScanner.nextInt();
        if (sScanner.hasNextInt()) maxVal = sScanner.nextInt();
        int Lc rows = 0;
```

```
int Lc cols = 0;
        int Lc value = 0;
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j \le numCols; j++) {
                if (sScanner.hasNextInt()) Lc rows = sScanner.nextInt();
                if (sScanner.hasNextInt()) Lc cols = sScanner.nextInt();
                if (sScanner.hasNextInt()) Lc value = sScanner.nextInt();
                zeroFramedAry[Lc rows][Lc cols] = Lc value;
            }
        }
    }
    void skeletonExpansionPass1(int zeroFramedAry[][], FileWriter of2) throws
IOException {
        of2.write("Results of 1st Expansion pass: \n");
        of2.write("\n");
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j <= numCols; j++) {</pre>
                if (zeroFramedAry[i][j] == 0) {
                    getMax(zeroFramedAry, i, j);
                }
            }
        }
    }
    void getMax(int zeroFramedAry[][], int i, int j) {
        neigh[0] = zeroFramedAry[i - 1][j - 1] - 1;
        neigh[1] = zeroFramedAry[i - 1][j] - 1;
        neigh[2] = zeroFramedAry[i - 1][j + 1] - 1;
        neigh[3] = zeroFramedAry[i][j - 1] - 1;
        neigh[4] = zeroFramedAry[i][j + 1] - 1;
        neigh[5] = zeroFramedAry[i + 1][j - 1] - 1;
        neigh[6] = zeroFramedAry[i + 1][j] - 1;
        neigh[7] = zeroFramedAry[i + 1][j + 1] - 1;
        int max;
        for (int k = 0; k < 8; k++) {
            max = neigh[k];
            if (zeroFramedAry[i][j] < max) {</pre>
                zeroFramedAry[i][j] = max;
        }
    }
    void skeletonExpansionPass2 (int zeroFramedAry[][], FileWriter of2) throws
IOException {
        of2.write("Results of 2nd Expansion pass: \n");
```

```
for (int i = numRows; i >= 1; i--) {
            for (int j = numCols; j >= 1; j--) {
                getMax2(zeroFramedAry, i, j);
            }
        }
        newMinVal = zeroFramedAry[0][0];
        newMaxVal = zeroFramedAry[0][0];
        for (int i = 1; i <= numRows; i++) {</pre>
            for (int j = 1; j <= numCols; j++) {</pre>
                if (zeroFramedAry[i][j] > newMaxVal) {
                    newMaxVal = zeroFramedAry[i][j];
                } else {
                    newMinVal = zeroFramedAry[i][j];
            }
        }
        of2.write(numRows + " " + numCols + " " + newMinVal + " " + newMaxVal
+ "\n");
    }
    void getMax2(int zeroFramedAry[][], int i, int j) {
        neigh[0] = zeroFramedAry[i - 1][j - 1];
        neigh[1] = zeroFramedAry[i - 1][j];
        neigh[2] = zeroFramedAry[i - 1][j + 1];
        neigh[3] = zeroFramedAry[i][j - 1];
        neigh[4] = zeroFramedAry[i][j + 1];
        neigh[5] = zeroFramedAry[i + 1][j - 1];
        neigh[6] = zeroFramedAry[i + 1][j];
        neigh[7] = zeroFramedAry[i + 1][j + 1];
        int max;
        for (int k = 0; k < 8; k++) {
            max = neigh[k];
            if (zeroFramedAry[i][j] < max) {</pre>
                zeroFramedAry[i][j] = Math.abs(max - 1);
        }
    void thresholdDecompression(int array[][], FileWriter of) throws
IOException {
        of.write("Results of Threshold Decompression: \n\n");
```

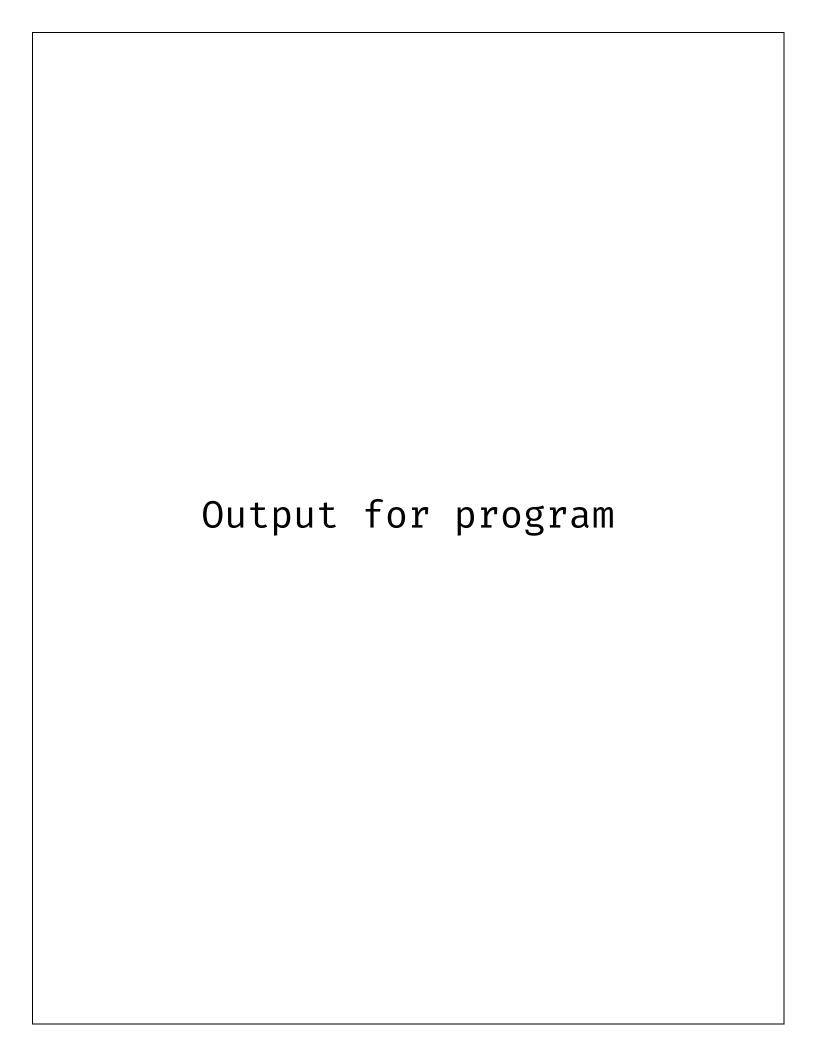
```
of.write(numRows + " " + numCols + " " + minVal + " " + maxVal +

for (int i = 1; i <= numRows; i++) {
    for (int j = 1; j <= numCols; j++) {

        if (array[i][j] >= 1) {
            of.write("1 ");
        } else {
            of.write("0 ");
        }

        of.write("\n");
    }

of.write("\n");
of.flush();
}
```



Data set 1.

Binary Image

30 40	0	1																																			
0 0 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0 0 0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0 0 0	0	0	0	0	0	0	1	1	1	0	0	0	_			0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 0 0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0 0 0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0 0 0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0		1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0 0 0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0 0 0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0 0 0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0 0 0	0	0	0	1	1	1	1	1	1	1	1	1	0			0	0		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	_	1
0 0 0	0	0	0	1	1	1	1	1	1	1	_	1	0	_	_	_	_	0		_		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0 0 0	0	0	_	1	1	1	1	1	1	1	1	1	0	_	_	0	_	_		_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	1	1		1	0	-		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	•	0
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	1	_	_	1	_	_	_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	•	0	_
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	_	_	0	_	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	•	0
0 0 0	_	1	1	1	1	1	1	1	1	1	1	_				1				_	1	_	1		1	1	1	1	1	1	0	0	0	0	0	•	0
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	1	1	_	1	_	_		_		_	1	1	1	1	1	1	1	0	0	0	0	0	0	•	0
	1	1	1	1	1	1	1	1	1	1	1	1				1								1	1	1	1	1	0	0	0	0	0	0	0	0	_
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	_	_	_	1	_	-	_	_	1			1	1	1	1	1	1	0	0	0	0	0	0	0	•
0 0 0		_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	•	0
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0 0 0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	U T	0	0	-	0	•
	_	1	_	1	1	1	1	1	1	1	1	_	1	_	-	1	1	_	1	1	_	_	-	1	1	1	1	1	1	1	0	0	0	0	0	0	•
	_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	U	0	0	0	0	0	•	0
0 0 0	_	1	1	1	1	1	1	1	1	1	1	1	1	1	_	1	_	1	_	_	_	_	1	1	1	1	1	1	0	0	0	0	0	0	0	•	0
0 0 0		1	1	1	1	1	1	1	1	1	1	_	1	_								_		0	_	0	0	0	0	0	0	0	0	0	•	0	_
0 0 0	_	_	_	1	1	1	1	1	1	1	1	1	_	1		0	_	_	_	_	_	_	_	0	_	_	0	0	0	0	0	0	0	0	0	•	0
0 0 0	_		0	1	1	1	1	1	1	1	1	1	1	0		0	_	0	_	0	0	_	_	0	_	0	0	0	0	0	0	0	0	0	0	•	0
0 0 0		_	_	_	_	_	1	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	0	_	-	_	_	_	_	_	_	0	0	_	0	•
0 0 0	U	U	U	U	_	_	_	_	_	_	_	_	U	U	U	U	U	U	U	0	0	0	0	0	U	U	0	U	U	U	U	U	U	U	U	U	0



Distance Transform Pass 1

Results of 1st Distance Transform Pass: 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 1 1 1 1 1 1 2 3 3 3 3 3 3 2 1 1 1 1 2 1 1 1 2 3 4 4 4 4 3 2 2 1 1 1 1 2 2 2 1 1 1 2 3 4 5 5 4 3 3 2 2 1 1 1 1 2 2 3 2 2 1 1 1 2 3 4 5 5 4 4 3 3 2 2 1 1 1 2 2 3 3 3 2 2 1 1 2 3 4 5 5 5 4 4 3 3 2 2 1 1 1 2 3 3 4 3 3 2 1 1 2 3 4 5 6 5 5 4 4 3 3 2 2 1 1 1 2 3 4 5 6 6 5 5 4 4 3 3 2 2 1 1 1 2 3 4 4 4 3 2 1 1 2 3 4 5 4 3 2 1 1 1 2 3 4 5 6 6 6 5 5 4 4 3 3 2 2 1 1 1 2 3 4 5 4 3 2 1 1 2 3 4 5 6 7 6 6 5 5 4 4 3 3 2 2 1 2 3 4 5 4 3 2 1 1 2 3 4 5 6 7 7 6 6 5 5 4 4 3 3 1 1 1 1 2 3 4 5 4 3 2 1 1 1 1 1 1 2 3 4 5 6 7 7 7 6 6 5 5 4 4 1 2 2 2 2 3 4 5 4 3 2 2 2 2 2 1 1 2 3 4 5 6 7 8 7 7 6 6 5 5 1 2 3 3 3 3 4 5 4 3 3 3 3 3 2 1 1 2 3 4 5 6 7 8 8 7 7 6 1 2 3 4 4 4 4 5 4 4 4 4 4 3 2 1 1 2 3 4 5 6 7 8 8 8 7 2 3 4 5 5 5 5 5 5 5 5 4 3 2 1 1 2 3 4 5 6 7 8 9 8 1 1 2 3 4 5 6 6 6 6 6 6 5 4 3 2 1 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 7 7 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 1 1 1 2 3 4 5 6 7 8 8 7 6 5 4 3 2 1 1 1 1 1 2 3 4 5 6 7 2 2 1 1 $1 \; 2 \; 3 \; 4 \; 5 \; 6 \; 7 \; 8 \; 8 \; 7 \; 6 \; 5 \; 4 \; 3 \; 2 \; 2 \; 2 \; 2 \; 2 \; 2 \; 2 \; 3 \; 4 \; 5 \; 6 \; 3 \; 3 \; 2 \; 2 \; 1 \; 1$



Results of 2nd Distance Transform Pass:

```
1 1 1 1 1 1 1 1 1 1
             1
                                    1 2 2 2 2 2 2 2 2 1
           1 1 1
                                   1 2 3 3 3 3 3 3 2 1 1
         1 1 2 1 1
                                   1 2 3 4 4 4 4 3 2 2 1 1
       1 1 2 2 2 1 1
                                   1 2 3 4 5 5 4 3 3 2 2 1 1
     1 1 2 2 3 2 2 1 1
                                   1 2 3 4 5 5 4 4 3 3 2 2 1 1
     1 2 2 3 3 3 2 2 1
                                   1 2 3 4 5 5 5 4 4 3 3 2 2 1 1
     1 2 3 3 4 3 3 2 1
                                   1 2 3 4 5 6 5 5 4 4 3 3 2 2 1 1
     1 2 3 4 4 4 3 2 1
                                   1 2 3 4 5 6 6 5 5 4 4 3 3 2 2 1 1
     1 2 3 4 5 4 3 2 1
                                1 1 2 3 4 5 6 6 5 5 5 4 4 3 3 2 2 1 1
     1 2 3 4 5 4 3 2 1
                                   1 2 3 4 5 6 5 5 4 4 4 3 3 2 2 1 1
                                   1 2 3 4 5 5 5 4 4 3 3 3 2 2 1 1
     1 2 3 4 5 4 3 2 1
                              1 2 3 4 5 5 4 4 3 3 2 2 1 1 1 1 2 3 4 5 4 3 3 2 2 1 1 1 1 1 2 3 4 5 4 3 3 2 2 1 1 1 1 1 2 3 4 5 4 3 3 2 1 1 1 1 2 3 4 5 4 3 2 1 1 1 1 2 3 4 5 4 3 2 1 1
1 1 1 1 2 3 4 5 4 3 2 1 1 1 1 1
                                   1 2 3 4 5 5 4 4 3 3 2 2 2 1 1
1 2 2 2 2 3 4 5 4 3 2 2 2 2 2 1
1 2 3 3 3 3 4 5 4 3 3 3 3 3 2 1
1 2 3 4 4 4 4 5 4 4 4 4 4 3 2 1
1 2 3 4 5 5 5 5 5 5 5 5 4 3 2 1
1 2 3 4 5 6 6 6 6 6 6 5 4 3 2 1
1 2 3 4 5 6 7 7 7 7 6 5 4 3 2 1 1 2 3 4 5 4 3 2 1 1
1 \; 2 \; 3 \; 4 \; 5 \; 6 \; 7 \; 7 \; 7 \; 7 \; 6 \; 5 \; 4 \; 3 \; 2 \; 1 \; 1 \; 1 \; 1 \; 1 \; 2 \; 3 \; 4 \; 5 \; 4 \; 3 \; 2 \; 2 \; 1 \; 1
1\ 2\ 3\ 4\ 5\ 6\ 6\ 7\ 7\ 6\ 6\ 5\ 4\ 3\ 2\ 2\ 2\ 2\ 2\ 2\ 2\ 3\ 4\ 5\ 4\ 3\ 3\ 2\ 2\ 1\ 1
1 1 2 2 3 3 4 4 3 3 2 2 1 1
   1 1 2 2 3 3 3 3 2 2 1 1
     1 1 2 2 2 2 2 2 1 1
       1 1 1 1 1 1 1 1
```

Results of Local Maxima: 1 2 5 5 5 5 3 6 4 5 6 6 5 1 6 6 5 5 4 3 2 1 5 5 5 5 5 5 6 7 7 7 7 7 7 7 7 7 7 4 3 2 1 6 6 4 4 4 4 4 4 4 4 4 5 5 4 4

Results of Lossless compression: 30 40 0 1 2 11 1 4 11 2 5 27 5 5 28 5 6 11 3 6 27 5 6 28 5 8 11 4 8 28 6 9 28 6 9 29 6 9 31 5 10 11 5 10 22 1 10 28 6 10 29 6 10 31 5 10 32 5 10 34 4 10 36 3 10 38 2 10 40 1 11 11 5 11 28 6 12 11 5 13 11 5 13 27 5 13 28 5 14 11 5 14 27 5 22 31 3 15 11 5 22 33 2 15 27 5 22 35 1 16 11 5 16 27 5 23 11 6 17 27 5 23 12 6 18 27 5 23 17 4 19 10 7 23 18 4 19 11 7 23 19 4 19 12 7 23 20 4 19 13 7 19 27 5 23 21 4 20 10 7 23 22 4 20 11 7 23 23 4 20 12 7 23 24 4 20 13 7 23 25 4 20 27 5 25 11 5 21 11 7 25 12 5 21 12 7 27 11 4 21 27 5 22 27 5 27 12 4 22 29 4

Results of 1st Expansion pass:

```
1
          1 1 1
          1 2 1
                                     4 4 4 4 3 2 1
          2 2 2 1
                                    3 4 5 5 4 3 2 1
        1 2 3 2 1
                                  2 3 4 5 5 4 3 2 1
        1 3 3 3 2 1
                                1 2 3 4 5 5 5 4 3 2 1
        2 3 4 3 2 1
                                1 2 3 4 5 6 5 5 4 4 3 2 1
      1 2 4 4 4 3 2 1
                                1 2 3 4 5 6 6 5 5 4 4 3 3 2 2 1 1
      1 3 4 5 4 3 2 1
                              1 1 2 3 4 5 6 6 5 5 5 4 4 3 3 2 2 1 1
      2 3 4 5 4 3 2 1
                                1 2 3 4 5 6 5 5 4 4 4 3 3 2 2 1 1
     1 2 3 4 5 4 3 2 1
                                1 2 3 4 5 5 5 4 4 3 3 3 2 2 1 1
     1 2 3 4 5 4 3 2 1
                                1 2 3 4 5 5 4 4 3 3 2 2 2 1 1
     1 2 3 4 5 4 3 2 1
                                1 2 3 4 5 4 4 3 3 2 2 1 1 1
      2 3 4 5 4 3 2 1
                                1 2 3 4 5 4 3 3 2 2 1 1
     1 2 3 4 5 4 3 2 1
                                1 2 3 4 5 4 3 2 2 1 1
     1 2 3 4 4 4 3 2 1
                                1 2 3 4 5 4 3 2 1 1
     1 2 6 6 6 6 6 6 5 4 3 2 1
                                1 2 3 4 5 4 3 2 1
     1 5 6 7 7 7 7 6 5 4 3 2 1
                                1 2 3 4 5 4 3 2 1
     4 5 6 7 7 7 7 6 5 4 3 2 1
                                1 2 3 4 5 4 3 2 1
   3 4 5 6 6 7 7 6 6 5 4 3 2 1
                                1 2 3 4 5 4 3 3 2 2 1 1
 2 3 4 5 5 6 6 6 6 5 5 4 3 3 3 3 3 3 3 3 3 4 5 4 4 3 3 2 2 1 1
1 1 2 2 3 3 4 4 4 4 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 2 2 3 3 4 4 3 3 2 2 1 1
   1 1 2 2 3 3 3 3 2 2 1 1
     1 1 2 2 2 2 2 2 1 1
       1 1 1 1 1 1 1 1
```

```
30 40 0 7
                                          1 1 1 1 1 1 1 1 1 1
                                          1 2 2 2 2 2 2 2 2 1
                   1
                 1 1 1
                                          1 2 3 3 3 3 3 3 2 1 1
               1 1 2 1 1
                                          1 2 3 4 4 4 4 3 2 2 1 1
             1 1 2 2 2 1 1
                                          1 2 3 4 5 5 4 3 3 2 2 1 1
           1 1 2 2 3 2 2 1 1
                                          1 2 3 4 5 5 4 4 3 3 2 2 1 1
           1 2 2 3 3 3 2 2 1
                                          1 2 3 4 5 5 5 4 4 3 3 2 2 1 1
           1 2 3 3 4 3 3 2 1
                                          1 2 3 4 5 6 5 5 4 4 3 3 2 2 1 1
           1 2 3 4 4 4 3 2 1
                                          1 2 3 4 5 6 6 5 5 4 4 3 3 2 2 1 1
           1 2 3 4 5 4 3 2 1
                                        1 1 2 3 4 5 6 6 5 5 5 4 4 3 3 2 2 1 1
           1 2 3 4 5 4 3 2 1
                                          1 2 3 4 5 6 5 5 4 4 4 3 3 2 2 1 1
           1 2 3 4 5 4 3 2 1
                                          1 2 3 4 5 5 5 4 4 3 3 3 2 2 1 1
     1 1 1 1 2 3 4 5 4 3 2 1 1 1 1 1
                                          1 2 3 4 5 5 4 4 3 3 2 2 2 1 1
     1 2 2 2 2 3 4 5 4 3 2 2 2 2 2 1
                                          1 2 3 4 5 4 4 3 3 2 2 1 1 1
     1 2 3 3 3 3 4 5 4 3 3 3 3 3 2 1
                                          1 2 3 4 5 4 3 3 2 2 1 1
       2 3 4 4 4 4 5 4 4 4 4 4 3 2 1
                                          1 2 3 4 5 4 3 2 2 1 1
       2 3 4 5 5 5 5 5 5 5 5 4 3 2 1
                                          1 2 3 4 5 4 3 2 1 1
                                          1 2 3 4 5 4 3 2 1
     1 2 3 4 5 6 6 6 6 6 6 5 4 3 2 1
     1 2 3 4 5 6 7 7 7 7 6 5 4 3 2 1
                                          1 2 3 4 5 4 3 2 1 1
       \begin{smallmatrix}2&3&4&5&6&7&7&7&7&6&5&4&3&2&1&1&1&1&1&2&3&4&5&4&3&2&2&1&1\end{smallmatrix}
       2 3 4 5 6 6 7 7 6 6 5 4 3 2 2 2 2 2 2 2 3 4 5 4 3 3 2 2 1 1
     1 2 3 4 5 5 6 6 6 6 5 5 4 3 3 3 3 3 3 3 3 3 4 5 4 4 3 3 2 2 1 1
     1 2 2 3 3 4 4 5 5 4 4 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1
     1\ 1\ 2\ 2\ 3\ 3\ 4\ 4\ 4\ 4\ 3\ 3\ 2\ 2\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1
       1 1 2 2 3 3 4 4 3 3 2 2 1 1
         1 1 2 2 3 3 3 3 2 2 1 1
           1 1 2 2 2 2 2 2 1 1
             1 1 1 1 1 1 1 1
```

Results of 2nd Expansion pass:

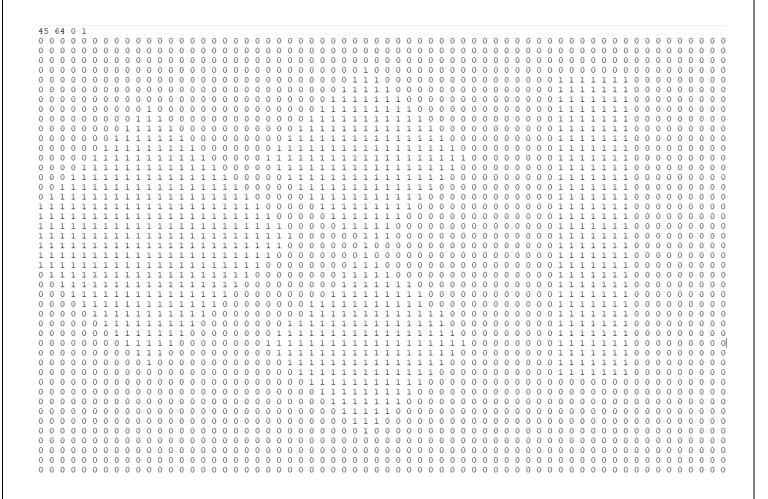


30 40 0 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 0 0 1 1 1 1 0 0 0 0 0

Results of Threshold Decompression:

Data set 2.

Binary Image





Distance Transform Pass 1

Results of 1st Distance Transform Pass:

```
1
1
2
2
3
3
4
4
5
4
3
2
1
                                                                                                                                                                                                                                                         1
2
2
3
3
4
4
5
6
                                                                                                                                                                                              1
2
2
3
3
4
4
3
2
1
                                                                                                                                                                               1
1 1
2 2 2
2 3
3 3
2 3
1 2
1
                                                                                                                                                                                                                                                                1
2
2
3
4
4
5
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2
2
3
3
4
                                                                                                                                                                        1
2
2
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2
2
3
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1
1
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1
2
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1
2
2
3
3
4
4
5
5
6
6
7
1
2
2
3
3
4
4
5
6
                                                                                                                                          1 1 2 1 1 2 2 1 3 2 2 3 3 2 4 3 3 4 4 5
                                                                                                                                                                 2
                                                                                                                                                                                                                                                         1
1
2
2
2
3
4
4
5
5
6
                                                                                                                                                                                                                                                                1
1 1
2 2
3 2
3 2
3 2
3 3
4 3
4 4
5
                                                                                                                                                                                                     1
1
2
3
3
3
4
5
4
3
2
1
                                                                                                                                                                                      1 1
1 2
1 2
2 2
3 3
3 4
3 4
2 3
1 2
                                                                                                                                                                                                                                                                               1
1
2
2
3
                                                                                                                                                                1
1 1
1 2
1 2
1
                                                                                                                                                                                1
2
3
2
1
                                                                                                                                                                                                                                                                                       1
1
2
                                                                                                                                                           1
```

Results of 2nd Distance Transform Pass:

1 1 1	1 2 2 2 2	1 2 3 3 3	1 2 2 3 3	1 2 3 3 4 4 4	1 2 3 3 4 4 5 4	1 2 2 3 3	1 2 2 3	1 2 2 3 3	1 1 2 2 3 3 4 4 5 5 6	1 1 2 2 3 3 4 4 5 5 6 6 7 7 7 6	1 2 2 3 3 4 4 5 5 6	1 2 2 3 3 4 4 5 5 6 6	1 2 3 3 4 4 5 5 6 5	1 2 2 3 3 4 4 5 5	1	1					1	1	2	1 2 2	1 2 2 3 2	1 2 3 3 3	1 2 3 4 3	1 2 2 3 4 4 4	1 2 3 3 4 4 5 4	3 4 4 5 5 5	1 2 3 3 4 4 5 4	1 2 3 3 4 4 4	1 2 3 3 4 3	1 2 3 3 3	1 2 3 2 2 1	1 2 2 2 1	1 2 1	1	1
	1	2	2 2 1	3 2 2 1	3 2 2 1	4 3 2 2 1	4 3 3 2 1	5 4 3 3 2 1	5 4 4 3 2 2	6 5 4 4	5 4 4 3 2 1	5 4 3 3 2 1	4 3 3 2 1	4 3 2 2 1	3 3 2 2 1 1	3 2 2 1 1	2 2 1 1	2 1 1	1	1	1		1	2 1	1 1 1 1 2 3 2 2 1 1	3 2 2	3 2 2 1	4 3 2 2 1	4 3 3 2 1	5 4 4 3 3	4 3 3 2 1	4 3 2 2 1	3 2 2 1	2 2 1	1 2 3 3 2 2	2 2 2 2 1	1	1	1

Results of Local Maxima:

												1	L				
												2	2				
			1									3	3				
			2									4	1				
			3					1	•	2			5		_	0	
			4					1	2	3	4	5 5	5 5	4	3	2	1
			5									4	1				
			6									3	3				
4	5	6	7 7 7 7	6	5	4	3	2	1				2				
4	5	6	7 7 7 7	6	5	4	3	2	1			1	L				
			6									2					
			5									3					
			4										4				
			3														
			2					1	2	3 3	3	5 5	5 5 5	4	3	2	1
			1							3	•	4					
												3					
												2	2				
												1					

Results of Lossless compression:

18 11 6

```
45 64 0 1
4 31 1
6 31 2
8 11 1
8 31 3
8 52 4
                                   18 31 3
9 52 4
                                                 28 11 4
                                   18 52 4
10 11 2
                                   19 52 4
                                                 28 52 4
10 31 4
                                   20 11 7
                                                  29 32 4
10 52 4
                                   20 32 2
                                                  29 52 4
11 52 4
                                   20 52 4
                                                  30 11 3
12 11 3
                                   21 4 4
                                                  30 52 4
12 31 5
                                   21 6 5
                                                  31 32 5
12 52 4
                                   21 8 6
                                                  31 36 3
13 22 1
                                   21 10 7
                                                  31 52 4
                                   21 11 7
13 24 2
                                                  32 11 2
                                   21 12 7
13 26 3
                                                  32 22 1
                                   21 14 6
13 28 4
                                                  32 24 2
                                   21 16 5
13 30 5
                                                  32 26 3
                                   21 18 4
13 31 5
                                                  32 27 3
                                   21 20 3
13 32 5
                                   21 22 2
                                                  32 30 5
13 34 4
                                                  32 31 5
                                   21 24 1
13 36 3
                                   21 52 4
                                                  32 32 5
13 38 2
                                   22 11 7
                                                  32 34 4
                                   22 31 1
13 40 1
                                                  32 36 3
                                   22 52 4
13 52 4
                                                  32 38 2
                                   23 31 1
                                                  32 40 1
14 11 4
                                   23 52 4
                                                  32 52 4
14 31 5
                                   24 11 6
                                                  33 27 3
14 52 4
                                   24 52 4
                                                  33 31 5
15 52 4
                                   25 31 2
                                                  34 11 1
16 11 5
                                   25 52 4
                                                  35 31 4
16 31 4
                                   26 11 5
                                                  37 31 3
16 52 4
                                   26 52 4
                                                  39 31 2
17 52 4
                                   27 31 3
```

41 31 1

27 52 4

Results of 1st Expansion pass:

```
1122334455554433321111122333344555443332211
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 1
1
2
2
3
3
4
4
5
4
4
3
3
2
2
2
1
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1
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1
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3
4
4
4
3
3
2
2
1
1
1
                                                                                                                                                        1122334455667665544332211
                                                                                                                                                                        \begin{matrix}1\\1\\2\\3\\3\\2\\4\\3\\3\\2\\2\\2\\1\\1\end{matrix}
                                                                                                                                                                                                                                                                                                                                                                                                                                                 1
2
4
4
4
3
3
2
1
1
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2
3
4
3
2
2
1
1
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3 2 2
3 3 2
3 2 2
2 2 1
2 1 1
1 1
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3
4
3
2
2
1
1
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1 2 2 3 3
1 1 2 2 3
1 1 2 2 3
1 1 2 2
1 1 2
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1
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5
4
4
3
3
2
2
1
1
                                                                                                            \begin{smallmatrix} 1 & 1 & 2 & 2 & 3 & 5 & 6 & 5 & 5 & 4 & 4 & 3 & 3 & 2 & 2 & 1 & 1 \\ \end{smallmatrix}
                                                                                                                                                                                                                                     1
1
2
4
5
4
4
3
3
2
2
1
1
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4
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                                          3 4 4
4 4 5
3 4 4
3 3 4
2 3 3
2 2 3
1 2 2
1 1 2
1 1
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4 3 3 2 2 1
3 3 2 2 1 1
3 2 2 1 1
2 2 1 1
2 1 1
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2
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1 2 2 3 3
1 1 2 2 3
1 1 2 2
1 1 2
1 1 1
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3
3
2
1
1
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                                                                                                                             1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2
1
1
```

Results of 2nd Expansion pass: 45 64 0 7

```
\begin{matrix} 1 \\ 1 \\ 2 \\ 2 \\ 3 \\ 3 \\ 4 \\ 4 \\ 5 \\ 4 \\ 4 \\ 3 \\ 3 \\ 2 \\ 2 \\ 1 \end{matrix}
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    \begin{matrix} 1 \\ 1 \\ 2 \\ 2 \\ 3 \\ 3 \\ 4 \\ 4 \\ 4 \\ 3 \\ 3 \\ 2 \\ 2 \\ 1 \\ 1 \\ 1 \end{matrix}
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     1
1
2
2
3
3
4
3
2
2
1
1
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2
2
3
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3
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2
2
3
2
1
1
                                                                                                                                                                                                        \begin{smallmatrix} 1 & 1 & 2 & 2 & 3 & 3 & 4 & 4 & 5 & 5 & 6 & 6 & 6 & 5 & 5 & 4 & 4 & 3 & 3 & 2 & 2 & 1 & 1 \\ \end{smallmatrix}
                                                                                                                                                                                                                                                                                  122334455667665544332211
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         1
2
2
1
1
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2
3
2
1
                                                                                                                                                                                                                                                                                                          \begin{matrix} 1 \\ 1 \\ 2 \\ 2 \\ 3 \\ 3 \\ 4 \\ 4 \\ 5 \\ 5 \\ 6 \\ 6 \\ 6 \\ 5 \\ 5 \\ 4 \\ 4 \\ 3 \\ 3 \\ 2 \\ 2 \\ 1 \\ 1 \end{matrix}
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        1
2
2
1
1
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2
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2
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3
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3
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