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Section: Image Processing

Project: **Project 7 - Chain Code**

Due Date: Nov 22nd

Algorithm Steps

```
Step 0: inFile, outFile1, deBugFile ← open via argv []
numRows, numCols, minVal, maxVal ← read from inFile
ZFAry, reConstructAry ← dynamically allocated and initialized to 0; in effect, arrays are zero framed.

Step 1: chainCodeFileName ← args [0] + "_chainCode.txt"
boundaryFileName ← args [0] + "_boundary.txt"

Step 2: chainCodeFile ← open (chainCodeFileName)
boundaryFile ← open (boundaryFileName)

Step 3: loadImage (inFile, ZFAry)
deBugFile ← "After loadImage; ZFAry as below"
reformatPrettyPrint (ZFAry, outFile1) // prettyPrint ZFAry to outFile1 (with dots).

Step 4: getChainCode (ZFAry, chainCodeFile, deBugFile)
deBugFile ← "After getChainCode; ZFAry as below"
reformatPrettyPrint (ZFAry, outFile1) // prettyPrint ZFAry to outFile1 (with dots).

Step 5: close chainCodeFile

Step 6: reopen chainCodeFile

Step 7: constructBoundary (reConstructAry, chainCodeFile)
reformatPrettyPrint (reConstructAry, outFile1) // prettyPrint reConstructAry to outFile1. Using dots.

Step 8: imgReformat (reConstructAry, boundaryFile) // NO dots.

Step 9: close all files
```

Video: https://www.youtube.com/watch?v=XKDSZgm96-k

Source Code:

```
#include <iostream>

#include <fstream>

#include <set>


using namespace std;


namespace Util{

    static int** getArray(int rows, int cols){

        int** array = new int*[rows];

        for(int i = 0; i < rows; i++){

            array[i] = new int[cols];

            for(int j = 0; j < cols; j++){

                array[i][j] = 0;

            }

        }

        return array;

    }

}


class Point{

public:

    int row;

    int col;


    Point(int row, int col){

        this->row = row;

        this->col = col;

    }


    Point(){

        this->row = 0;
        this->col = 0;
    }

    void setIndex(int row, int col){
        this->row = row;
        this->col = col;
    }

    void moveDirection(Point& other){
        setIndex(this->row + other.row, this->col + other.col);
    }

    bool operator!=(const Point& other){
        return !(this->row == other.row && this->col == other.col);
    }
};

class ChainCode{
public:
    int numRows,
        numCols,
        minVal,
        maxVal,
        label;
    int** zeroFramedAry;
    int** reconstructAry;
    Point coordOffset[8] = {Point(0, 1), Point(-1, 1), Point(-1, 0), Point(-1, -1), Point(0, -1), Point(1, -1), Point(1, 0), Point(1, 1)};
    int zeroTable[8] = {6, 0, 0, 2, 2, 4, 4, 6};
    Point startPoint;
    Point currentPoint;
    Point neighborCoord;
    int lastZeroDirection;
    int chainDirection;
```

```
ChainCode(ifstream& inFile){
    inFile >> numRows >> numCols >> minVal >> maxVal;
    zeroFramedAry = Util::getArray(numRows + 2, numCols + 2);
    reconstructAry = Util::getArray(numRows + 2, numCols + 2);
    label = 1;
    loadImg(inFile);
}

void loadImg(ifstream& inFile){
    for(int i = 1; i < numRows + 1; i++){
        for(int j = 1; j < numCols + 1; j++){
            inFile >> zeroFramedAry[i][j];
        }
    }
}

void imageReformat(int** image, ofstream& outFile){
    outFile << numRows << " " << numCols << " " << minVal << " " << maxVal << '\n';
    string str;
    int curWidth,
        pixelWidth = to_string(maxVal).length();

    for(int r = 1; r < numRows + 1; r++){
        for(int c = 1; c < numCols + 1; c++){
            outFile << image[r][c];
            str = to_string(image[r][c]);
            curWidth = str.length();
            while(curWidth < pixelWidth){
                outFile<<' ';
                curWidth++;
            }
            outFile<<' ';
        }
        outFile << '\n';
    }
}

void reformatPrettyPrint(int** image, ofstream& outFile){
    outFile << numRows << " " << numCols << " " << minVal << " " << maxVal << '\n';
    string str;
    int curWidth,
        pixelWidth = to_string(maxVal).length();

    for(int r = 1; r < numRows + 1; r++){
        for(int c = 1; c < numCols + 1; c++){
            outFile << (image[r][c] == 0 ? "." : to_string(image[r][c]));
            str = to_string(image[r][c]);
            curWidth = str.length();
            while(curWidth < pixelWidth){
                outFile<<' ';
                curWidth++;
            }
            outFile<<' ';
        }
        outFile << '\n';
    }
}

void getChainCode(ofstream& chainCodeFile, ofstream& debugFile){
    debugFile << "Entering getChainCode\n";
    chainCodeFile << numRows << " " << numCols << " " << minVal << " " << maxVal << '\n';

    bool foundStartPoint = false;
    for(int i = 0; i < numRows + 2; i++){
        if (foundStartPoint) break;
        for(int j = 0; j < numCols + 2; j++){
            if(zeroFramedAry[i][j] == 0) continue;
```

```
                label = zeroFramedAry[i][j];
                startPoint.setIndex(i, j);
                currentPoint.setIndex(i, j);
                lastZeroDirection = 4;
                // break the loop
                foundStartPoint = true;
                break;
            }
        }

        chainCodeFile << label << " " << startPoint.row << " " << startPoint.col << " ";

        do{
            lastZeroDirection = (lastZeroDirection + 1) % 8;
            chainDirection = findNextPoint(debugFile);
            chainCodeFile << chainDirection << " ";

            currentPoint.moveDirection(coordOffset[chainDirection]);
            zeroFramedAry[currentPoint.row][currentPoint.col] = label + 4;
            // lastZeroDirection is the direction of the same zero for the next point
            // for example, if next point direction is 4, that means the last zero direction is 3
            // 3 is the direction of last zero for current point
            // and the last zero is at the direction of 2 for next point
            lastZeroDirection = zeroTable[((chainDirection + 6) % 8)];
            debugFile << "lastZeroDirection: " << lastZeroDirection << " "
                      << "currentPoint: " << currentPoint.row << " " << currentPoint.col << " "
                      << "nextPoint: " << currentPoint.row + coordOffset[chainDirection].row << "
"
                      << currentPoint.col + coordOffset[chainDirection].col << "\n";
        }while(currentPoint != startPoint);
        chainCodeFile << '\n';
        debugFile << "Leaving getChainCode \n";
    }

    int findNextPoint(ofstream& debugFile){
```

```
    debugFile << "Entering findNextPoint\n";
    int index = lastZeroDirection;
    bool isFound = false;
    int i, j;
    while(!isFound){
        i = currentPoint.row + coordOffset[index].row;
        j = currentPoint.col + coordOffset[index].col;

        if(zeroFramedAry[i][j] == label || zeroFramedAry[i][j] == label + 4) {
            isFound = true;
            chainDirection = index;
        }else{
            index = (index + 1) % 8;
        }
    }
    debugFile << "Leaving findNextPoint\n";
    return chainDirection;
}

void constructBoundary(ifstream& chainCodeFile){
    int label, row, col, chainCode;
    // pass the headers: numRows, numCols, minVal, maxVal
    for(int i = 0; i < 4; i++){
        chainCodeFile >> label;
    }
    chainCodeFile >> label >> row >> col;
    reconstructAry[row][col] = label;
    while(chainCodeFile >> chainCode){
        row += coordOffset[chainCode].row;
        col += coordOffset[chainCode].col;
        reconstructAry[row][col] = label;
    }
}
```

```
    ~ChainCode(){
        for(int i = 0; i < numRows + 2; i++){
            delete[] zeroFramedAry[i];
            delete[] reconstructAry[i];
        }
        delete[] zeroFramedAry;
        delete[] reconstructAry;
    }
};

int main(int argc, const char* args[]){
    // Read in the file
    ifstream inFile(args[1]);
    ofstream outFile(args[2]),
             debugFile(args[3]),
             chainCodeFile(args[1] + string("_chainCode.txt")),
             boundaryFile(args[1] + string("_boundary.txt"));

    ChainCode chainCode(inFile);
    debugFile<< "After loadImage, zeroFramedAry: \n";
    outFile << "After loadImage, zeroFramedAry: \n";
    chainCode.reformatPrettyPrint(chainCode.zeroFramedAry, outFile);

    chainCode.getChainCode(chainCodeFile, debugFile);
    debugFile<< "After getChainCode, zeroFramedAry: \n";
    outFile << "\n\nAfter getChainCode, zeroFramedAry: \n";
    chainCode.reformatPrettyPrint(chainCode.zeroFramedAry, outFile);

    chainCodeFile.close();
    ifstream chainCodeFileIn(args[1] + string("_chainCode.txt"));
    chainCode.constructBoundary(chainCodeFileIn);

    outFile << "\n\nAfter constructBoundary, reconstructAry: \n";
    chainCode.reformatPrettyPrint(chainCode.reconstructAry, outFile);
    chainCode.imageReformat(chainCode.reconstructAry, boundaryFile);

    return 0;
}
```

Program Output

Img1 OutFile

```
After loadImage, zeroFramedAry:
20 40 0 5
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . 5 . . . . . . . 5 5 5 . . . . . . . . . . 5 . . . . . . . . .
. . . . . . . . 5 5 5 . . . . . . 5 5 5 . . . . . . . . . 5 5 5 . . . . . . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . . . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . . . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . 5 . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . 5 . . 5 5 5 . . . . 5 . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . 5 . . 5 5 5 . . . . 5 . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 5 5 5 5 5 5 5 5 5 . . 5 5 5 . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 . . .
. . . . . . . 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . 5 . . .
. . . . . . . 5 5 5 5 5 . . . . . 5 5 5 . . . . . . . . 5 5 5 5 5 . . . . . . .
. . . . . . . . 5 5 5 . . . . . . 5 5 5 . . . . . . . . . 5 5 5 . . . . . . . .
. . . . . . . . . 5 . . . . . . . 5 5 5 . . . . . . . . . . 5 . . . . . . . . .
```

```
After getChainCode, zeroFramedAry:
20 40 0 5
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . 9 . . . . . . . 9 9 9 . . . . . . . . . . 9 . . . . . . . . .
. . . . . . . . 9 5 9 . . . . . . 9 5 9 . . . . . . . . . 9 5 9 . . . . . . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . . . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . . . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . 9 . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . 9 . . 9 5 9 . . . . 9 . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . 9 . . 9 5 9 . . . . 9 . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 5 9 9 5 9 9 5 5 5 9 . . 9 5 9 . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 5 5 5 5 5 5 5 5 5 5 9 9 5 5 5 9 9 5 5 5 5 5 9 9 9 9 . . .
. . . . . . . 9 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 5 9 9 9 9 9 5 5 5 9 9 9 9 9 9 9 9 5 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . 9 . . .
. . . . . . . 9 5 5 5 9 . . . . . 9 5 9 . . . . . . . . 9 5 5 5 9 . . . . . . .
. . . . . . . . 9 5 9 . . . . . . 9 5 9 . . . . . . . . . 9 5 9 . . . . . . . .
. . . . . . . . . 9 . . . . . . . 9 9 9 . . . . . . . . . . 9 . . . . . . . . .
```

```
After constructBoundary, reconstructAry:
20 40 0 5
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . 5 . . . . . . . 5 5 5 . . . . . . . . . . 5 . . . . . . . . .
. . . . . . . . 5 . 5 . . . . . . 5 . 5 . . . . . . . . . 5 . 5 . . . . . . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . . . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . . . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . 5 . . 5 . 5 . . . . . . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . 5 . . 5 . 5 . . . . 5 . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . 5 . . 5 . 5 . . . . 5 . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . . 5 5 . 5 5 . . . 5 . . 5 . 5 . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . . . . . . . . . . . 5 5 . . . 5 5 . . . . . 5 5 5 5 . . .
. . . . . . . 5 . . . . . . . . . . . . . . . . . . . . . . . . 5 . . . 5 . . .
. . . . . . . 5 . . . . 5 5 5 5 5 . . . 5 5 5 5 5 5 5 5 . . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . 5 . . .
. . . . . . . 5 . . . 5 . . . . . 5 . 5 . . . . . . . . 5 . . . 5 . . . . . . .
. . . . . . . . 5 . 5 . . . . . . 5 . 5 . . . . . . . . . 5 . 5 . . . . . . . .
. . . . . . . . . 5 . . . . . . . 5 5 5 . . . . . . . . . . 5 . . . . . . . . .
```

Img1 ChainCodeFile

```
20 40 0 5
5 2 10 5 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 7 7 1 1 2 2 2 1 0 0 0 0 7
6 6 6 6 6 0 0 2 2 2 2 2 1 0 0 0 0 0 0 0 7 6 6 6 7 7 1 1 2 2 2 2
2 1 0 0 7 6 6 6 6 2 2 2 2 2 2 2 2 2 2 2 2 6 6 6 6 6 5 4 4 3 2 2 2
```

```
2 2 2 2 3 3 5 5 6 6 6 6 6 6 6 5 4 3 3 2 6 5 5 4 3 3 2 2 2 2 2 2
2 2 4 4 6 6 6 6 6 6 6 6 5 4 3 2 2 6 6 5 4 3 2 2 2 2 2 2 3 3
```

Img1 BoundaryFile

```
20 40 0 5
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 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 5 5 5 0 0 0 0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 5 0 5 0 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 5 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 5 0 0 5 0 5 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 5 0 0 5 0 5 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 0 5 5 0 5 5 0 0 0 5 0 0 5 0 5 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 0 0 0 0 0 0 5 5 0 0 0 5 5 0 0 0 0 0 5 5 5 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 0 5 5 5 5 5 0 0 0 5 5 5 5 5 5 5 5 0 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 5 0 0 0
0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 5 0 0 0 5 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 5 0 5 0 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0 0 5 0 5 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 5 5 5 0 0 0 0 0 0 0 0 0 0 5 0 0 0 0 0 0 0 0 0
```

Img1 Debug

```
After loadImage, zeroFramedAry:

Entering getChainCode

Entering findNextPoint

Leaving findNextPoint
```

```
lastZeroDirection: 2 currentPoint: 3 9 nextPoint: 4 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 4 8 nextPoint: 5 7
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 5 8 nextPoint: 6 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 6 8 nextPoint: 7 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 7 8 nextPoint: 8 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 8 8 nextPoint: 9 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 9 8 nextPoint: 10 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 10 8 nextPoint: 11 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 11 8 nextPoint: 12 8
Entering findNextPoint
```

```
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 12 8 nextPoint: 13 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 13 8 nextPoint: 14 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 14 8 nextPoint: 15 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 15 8 nextPoint: 16 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 16 8 nextPoint: 17 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 17 8 nextPoint: 18 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 18 8 nextPoint: 19 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 19 9 nextPoint: 20 10
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 20 10 nextPoint: 21 11
```

```
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 6 currentPoint: 19 11 nextPoint: 18 12
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 6 currentPoint: 18 12 nextPoint: 17 13
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 6 currentPoint: 17 12 nextPoint: 16 12
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 6 currentPoint: 16 12 nextPoint: 15 12
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 6 currentPoint: 15 12 nextPoint: 14 12
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 6 currentPoint: 14 13 nextPoint: 13 14
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 14 14 nextPoint: 14 15
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 14 15 nextPoint: 14 16
Entering findNextPoint
Leaving findNextPoint
```

Img2 OutFile

After loadImage, zeroFramedAry:

```
20 40 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 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 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 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 . . . . .
. . . . 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 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 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 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 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 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 1 1 1 1 1 1 1 1 1 1 . . 1 1 1 . . . . . . . .
. . . . . . . . . 1 1 . . . . . . 1 1 1 . . . 1 1 . . . . . 1 . . . . . . . . .
. . . . . . . . . 1 . . . . . . . . 1 . . . . . 1 . . . . . . . . . . . . . . .
```

After getChainCode, zeroFramedAry:

```
20 40 0 1
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . 5 . . . . . . . . . . . . . . . . . . . . . . 5 . . . . . . . . .
. . . . . . . 5 . . . . . . . . . . . . . . . . . . . . . 5 1 5 . . . . . . . .
. . . . . 5 5 1 5 5 . . . . . . . . . . . . . . . . . . 5 1 1 1 5 . . . . . . .
. . . . 5 1 1 1 1 5 . . . . . . . . . . . . . . . . . 5 1 1 1 1 1 5 . . . . . .
. . . . . 5 5 1 1 5 . . . . . . 5 . . . . . . . . . 5 1 1 1 1 1 1 1 5 . . . . .
. . . . . . . 5 1 5 . . . . . . 5 . . . . . . . . 5 1 1 1 1 1 1 1 1 1 5 . . . .
. . . . 5 5 5 1 1 5 . . . . . . 5 . . . . . . . 5 1 1 1 1 1 1 1 1 1 1 1 5 . . .
. . . . 5 1 1 1 1 5 . . . . . 5 1 5 . . . . . 5 5 5 1 1 1 1 1 1 1 1 1 5 5 5 . .
. . . . 5 1 1 1 1 5 . . . . 5 1 1 1 5 . . . . . . . 5 1 1 1 1 1 1 1 5 . . . . .
. . . . 5 1 1 1 1 5 . . . 5 1 1 1 1 5 . . . . . . . . 5 5 1 1 1 5 5 . . . . . .
. . . . 5 1 1 1 1 1 5 . 5 1 1 1 1 1 1 5 . . . . . . . . . 5 1 5 . . . . . . . .
. . . . 5 1 1 1 1 1 1 5 1 1 1 1 1 1 1 1 5 . . 5 5 5 5 5 5 1 1 1 5 5 5 5 5 5 . .
. . . . 5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 5 . . . 5 1 1 1 1 1 1 1 1 1 1 1 5 . . .
. . . . 5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 5 . . . . 5 1 1 1 1 1 1 1 1 5 5 . . . .
. . . . . 5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 5 . . . 5 1 1 5 1 1 1 1 1 5 . . . . . .
. . . . . . 5 1 1 1 1 1 5 5 5 1 1 1 1 1 1 5 5 5 1 1 5 . 5 1 1 1 5 . . . . . . .
. . . . . . . 5 5 1 1 5 . . . 5 5 1 1 1 5 5 5 1 1 5 5 . . 5 1 5 . . . . . . . .
. . . . . . . . . 5 5 . . . . . . 5 1 5 . . . 5 5 . . . . . 5 . . . . . . . . .
. . . . . . . . . 5 . . . . . . . . 5 . . . . . 5 . . . . . . . . . . . . . . .


After constructBoundary, reconstructAry:

20 40 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 . . . . . . 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 . . . . . . . . . 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 . . . . . .
. . . . . . 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 . . . . . 1 . . . . . . . . . . . . . . .
```

Img2 ChainCodeFile

```
20 40 0 1

1 2 8 6 5 4 5 7 0 7 5 4 4 6 6 6 6 6 6 6 7 7 7 0 7 6 1 1 1 0 0 7
0 7 7 1 1 0 0 7 7 2 1 0 2 1 7 7 7 1 1 1 1 0 1 1 4 4 4 4 4 3 1 0
1 1 0 0 3 3 3 3 3 3 3 5 5 5 5 5 5 5 0 0 7 7 0 7 5 4 4 4 4 4 7 7
5 5 4 4 3 2 2 2 3 3 2 3 3 2 2 6 6 5 5 5 5 5 3 3 2 2 2 2 2 2 2 4
3 2
```

Img2 BoundaryFile

```
20 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 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 0 0 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 0 0
0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0
0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 1 1 1 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0
0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 1 1 1 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 1 0 1 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 1 1 1 0 0
0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0
0 0 0 0 1 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 1 1 0 0 0 1 1 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0
```

```
0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 0 0
0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 1 1 0 0 0 0
0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 0 1 0 0 0 0 0 1 1 1 0 0 0 0 0 0 1 1 1 0 0 1 0 1 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 1 1 0 0 0 1 1 1 0 0 1 1 0 0 1 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 1 0 0 0 1 1 0 0 0 0 0 1 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 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

Img2 Debug

```
After loadImage, zeroFramedAry:

Entering getChainCode

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 3 8 nextPoint: 4 8

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 4 7 nextPoint: 5 6

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 0 currentPoint: 4 6 nextPoint: 4 5

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 5 5 nextPoint: 6 4

Entering findNextPoint

Leaving findNextPoint
```

```
lastZeroDirection: 4 currentPoint: 6 6 nextPoint: 7 7

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 4 currentPoint: 6 7 nextPoint: 6 8

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 4 currentPoint: 7 8 nextPoint: 8 9

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 8 7 nextPoint: 9 6

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 0 currentPoint: 8 6 nextPoint: 8 5

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 0 currentPoint: 8 5 nextPoint: 8 4

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 9 5 nextPoint: 10 5

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 10 5 nextPoint: 11 5

Entering findNextPoint

Leaving findNextPoint

lastZeroDirection: 2 currentPoint: 11 5 nextPoint: 12 5

Entering findNextPoint
```

```
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 12 5 nextPoint: 13 5
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 13 5 nextPoint: 14 5
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 14 5 nextPoint: 15 5
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 2 currentPoint: 15 5 nextPoint: 16 5
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 16 6 nextPoint: 17 7
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 17 7 nextPoint: 18 8
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 18 8 nextPoint: 19 9
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 18 9 nextPoint: 18 10
Entering findNextPoint
Leaving findNextPoint
lastZeroDirection: 4 currentPoint: 19 10 nextPoint: 20 11
```