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Algorithm Steps:

Main(…)

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step 0: imgFile, structFile, dilateOutFile, erodeOutFile, openingOutFile, closingOutFile, prettyPrintFile ← open

step 1: numImgRows, numImgCols, imgMin, imgMax ← read from imgFile

numStructRows, numStructCols, structMin, structMax ← read from structFile

rowOrigin, colOrigin read from strucFile

step 2: zeroFramedAry, structAry, morphAry, tempAry ← dynamically allocate // see description in the above

step 3: zero2DAry(zeroFramedAry, rowSize, colSize) // see description in the above

step 4: loadImg (imgFile, zeroFramedAry) // see description in the above

prettyPrint (zeroFramedAry, prettyPrintFile) // write a meaningful caption before prettyPrint

step 5: zero2DAry(structAry, numStructRows, numStructCols)

loadstruct (structFile, structAry) // see description in the above

prettyPrint (structAry, prettyPrintFile) // see description in the above

step 6: zero2DAry(morphAry, rowSize, colSize)

ComputeDilation (zeroFramedAry, morphAry) // see algorithm below

AryToFile (morphAry, dilateOutFile) // see description in the above

prettyPrint (morphAry, prettyPrintFile) // write a meaningful caption before prettyPrint

step 7: zero2DAry(morphAry, rowSize, colSize)

ComputeErosion (zeroFramedAry, morphAry) // see algorithm below

AryToFile (morphAry, erodeOutFile)

prettyPrint (morphAry, prettyPrintFile) // write a meaningful caption before prettyPrint

step 8: zero2DAry(morphAry, rowSize, colSize)

ComputeOpening (zeroFramedAry, morphAry, tempAry) // see algorithm below

AryToFile (morphAry, openingOutFile)

prettyPrint (morphAry, prettyPrintFile) // write a meaningful caption before prettyPrint

step 9: zero2DAry(morphAry, rowSize, colSize)

ComputeClosing (zeroFramedAry, morphAry, tempAry) // see algorithm below

AryToFile (morphAry, closingOutFile)

prettyPrint (morphAry, prettyPrintFile) // write a meaningful caption before prettyPrint

step 10: close all files

ComputeDilation (inAry, outAry)

step 1: i ← rowFrameSize

step 2: j ← colFrameSize

step 3: if inAry [i,j] > 0

onePixelDilation (i, j, inAry, outAry) // only processing one pixel inAry[i,j]

step 4: j++

step 5: repeat step 3 to step 4 while j < (colSize)

step 6: i++

step 7: repeat step 2 to step 6 while i < (rowSize)

ComputeErosion(inAry, outAry)

step 1: i ← rowFrameSize

step 2: j ← colFrameSize

step 3: if inAry[i,j] > 0

onePixelErosion (i, j, inAry, outAry) // only processing one pixel inAry[i,j]

step 4: j++

step 5: repeat step 3 to step 4 while j < (colSize)

step 6: i++

step 7: repeat step 2 to step 6 while i < (rowSize)

onePixelErosion(i, j, inAry, outAry)

step 0 : iOffset □ i - rowOrigin

jOffset □ j - colOrigin

// translation of image's coordinate (i, j) with respected of the origin of the structuring element

matchFlag ← true

step 1: rIndex ← 0

step 2: cIndex ← 0

step 3: if (structAry[rIndex][cIndex] > 0) and (inAry[iOffset + rIndex][jOffset + cIndex]) <= 0)

matchFlag ← false

step 4: cIndex ++

step 5: repeat step 3 to step 4 while (matchFlag == true) and (cIndex < numStructCols)

step 6: rIndex ++

step 7: repeat step 2 to step 6 while (matchFlag == true) and (rIndex < numStructRows)

step 8: if matchFlag == true

outAry[i][j] ← 1

else

outAry[i][j] □ 0

ComputeClosing(inAry, outAry, tempAry)

step 1: ComputeDilation (zeroFramedAry, tempAry)

step 2: ComputeErosion (tempAry, morphAry)

ComputeOpening(inAry, outAry, tempAry)

step 1: Compute Erosion (zeroFramedAry, tempAry)

step 2: ComputeDilation (tempAry, morphAry)

onePixelDilation(inAry, outAry)

1) Offset x and y by -1
2) Replace value at offset position with structure element
3) Increment x
4) Repeat step 2 until end of row
5) Increment y
6) Repeat until end of columns

Source Code

Main Class

```
int main( int argc, const char * argv[] ) {

    if(argc != 8){
        cout << "Invalid amount of arguments";
        exit(1);
    }

    string imgFile = argv[ 1 ] ;
    string structFile = argv[ 2 ];
    ifstream  imgStream, structStream ;

    imgStream.open( imgFile ) ;
    structStream.open( structFile );

    string dilateOutFile = argv[ 3 ] ;
    string erodeOutFile = argv[ 4 ];
    string closingOutFile = argv[ 5 ];
    string openingOutFile = argv[ 6 ];
    string prettyPrintFile = argv[ 7 ];

    ofstream dilateStream, erodeStream, closingStream, openingStream, prettyPrintStream ;
    dilateStream.open( dilateOutFile ) ;
    erodeStream.open( erodeOutFile );
    closingStream.open( closingOutFile );
    openingStream.open( openingOutFile );
    prettyPrintStream.open( prettyPrintFile );
```

```
if( imgStream.is_open() && structStream.is_open() ){
        // step 1 & 2
        Morphology* morphObj = new Morphology( imgStream, structStream );

        // step 3
        morphObj -> zero2DAry(morphObj -> zeroFramedAry, morphObj -> rowSize, morphObj -> colSize );

        // step 4
        morphObj -> loadImg( imgStream, morphObj -> zeroFramedAry );
        morphObj -> prettyPrint( morphObj -> zeroFramedAry, prettyPrintStream );

        // step 5
        morphObj -> zero2DAry( morphObj -> structAry, morphObj -> numStructRows, morphObj -> numStructCols );
        morphObj -> loadStruct( structStream, morphObj -> structAry );
        morphObj -> prettyPrint( morphObj -> structAry, prettyPrintStream);

        // step 6
        morphObj -> zero2DAry( morphObj -> morphAry, morphObj -> rowSize, morphObj -> colSize );
        morphObj -> computeDilation( morphObj -> zeroFramedAry, morphObj -> morphAry);
        morphObj -> aryToFile( morphObj -> morphAry, dilateStream );
        morphObj -> prettyPrint( morphObj -> morphAry, prettyPrintStream);

        // step 7
        morphObj -> zero2DAry( morphObj -> morphAry, morphObj -> rowSize, morphObj -> colSize );
        morphObj -> computeErosion( morphObj -> zeroFramedAry, morphObj -> morphAry);
        morphObj -> aryToFile( morphObj -> morphAry, erodeStream );
        morphObj -> prettyPrint( morphObj -> morphAry, prettyPrintStream);
```

```
        // step 9
        morphObj -> zero2DAry( morphObj -> morphAry, morphObj -> rowSize, morphObj -> colSize );
        morphObj -> computeClosing( morphObj -> zeroFramedAry, morphObj -> morphAry, morphObj -> tempAry);
        morphObj -> aryToFile( morphObj -> morphAry, openingStream );
        morphObj -> prettyPrint( morphObj -> morphAry, prettyPrintStream );

        // step 10
        imgStream.close() ;
        structStream.close();
        dilateStream.close() ;
        erodeStream.close();
        closingStream.close();
        openingStream.close();
        delete morphObj ;
    }
    else{
        cout << "Error: Input" << endl ;
    }

    return 0;
}
```

Morphology Class

```
class Morphology{
    public:
        int numImgRows,
            numImgCols,
            imgMin,
            imgMax,
            numStructRows,
            numStructCols,
            structMin,
            structMax,
            rowOrigin,
            colOrigin,
            rowFrameSize,
            colFrameSize,
            extraRows,
            extraCols,
            rowSize,
            colSize,
            msgCounter;

        int **zeroFramedAry, **morphAry, **tempAry, **structAry;
```

Constructor

```
public:
    Morphology( ifstream &imgFile, ifstream &structFile ){
        read_img_header( imgFile );
        read_struct_header( structFile );
        read_origin( structFile );

        this -> rowFrameSize = this -> numStructRows / 2;
        this -> colFrameSize  = this -> numStructCols / 2;

        this -> extraRows = this -> rowFrameSize * 2;
        this -> extraCols = this -> colFrameSize * 2;
        this -> rowSize = this -> numImgRows + this -> extraRows;
        this -> colSize = this -> numImgCols + this -> extraCols;

        this -> zeroFramedAry = new int*[ rowSize ];
        this -> morphAry = new int*[ rowSize ];
        this -> tempAry = new int*[ rowSize ];

        for(int i = 0; i < this -> rowSize; i++){
            zeroFramedAry[i] = new int[ this -> colSize ];
            morphAry[i] = new int[ this -> colSize ];
            tempAry[i] = new int[ this -> colSize ];
        }

        this -> structAry = new int*[ this -> numStructRows ];

        for(int i = 0; i < this -> numStructRows; i++){
            structAry[i] = new int[ this -> numStructCols ];
        }

        this -> msgCounter = 0;
    }
```

Read Headers and origin

```
void read_img_header( ifstream &inFile ){
    inFile >> this -> numImgRows >> this -> numImgCols >> this -> imgMin >> this -> imgMax ;
}

void read_struct_header( ifstream &inFile ){
    inFile >> this -> numStructRows >> this -> numStructCols >> this -> structMin >> this -> structMax ;
}

void read_origin( ifstream &inFile ){
    inFile >> this -> rowOrigin >> this -> colOrigin;
}
```

Zero2DAry

```
void zero2DAry(int **ary, int nRows, int nCols){
    for(int i = 0; i < nRows; i++){
        for(int j = 0; j < nCols; j++){
            ary[i][j] = 0;
        }
    }
}
```

loadImg

```
void loadImg( ifstream &inFile, int **ary){
    for( int i = this -> rowOrigin; i < this -> numImgRows; i++){
        for( int j = this -> colOrigin; j < this -> numImgCols; j++){
            inFile >> ary[i][j];
        }
    }
}
```

loadStruct

```
void loadStruct( ifstream &inFile, int **ary){
    for( int i = 0; i < this -> numStructRows; i++ ){
        for( int j = 0; j < this -> numStructCols; j++){
            inFile >> ary[i][j];
        }
    }
}
```

computeDilation

```
void computeDilation( int **inAry, int **outAry){
    for( int i = this -> rowFrameSize; i < this -> rowSize; i++ ){
        for(int j = this -> colFrameSize; j < this -> colSize; j++ ){
            if( inAry[i][j] > 0 ) this -> onePixelDilation(i,j, inAry, outAry);
        }
    }
}
```

computeErosion

```
void computeErosion( int **inAry, int **outAry ){
    for( int i = this -> rowFrameSize; i < this -> rowSize; i++ ){
        for(int j = this -> colFrameSize; j < this -> colSize; j++ ){
            if( inAry[i][j] > 0 ) this -> onePixelErosion(i,j, inAry, outAry);
        }
    }
}
```

computeOpening

```
void computeOpening( int **inAry, int **outAry, int **tmp){
    this -> computeErosion(inAry, tmp);
    this -> computeDilation(tmp, outAry);
}
```

computeClosing

```
void computeClosing( int **inAry, int **outAry, int **tmp){
    this -> computeDilation(inAry, tmp);
    this -> computeErosion(tmp, outAry);
}
```

onePixelDilation

```
void onePixelDilation(int i, int j, int **inAry, int **outAry){
    int structRow = 0;
    int structCol = 0;

    for( int r = i - 1; r <= i + 1; r++ ){
        for( int c = j - 1; c <= j + 1; c++ ){
            if(this -> structAry[ structRow ][ structCol ] == 1){
                outAry[r][c] = this -> structAry[ structRow ][ structCol ];
            }
            structCol++;
        }
        structCol = 0;
        structRow++;
    }

}
```

onePixelErosion

```
void onePixelDilation(int i, int j, int **inAry, int **outAry){
    int structRow = 0;
    int structCol = 0;

    for( int r = i - 1; r <= i + 1; r++ ){
        for( int c = j - 1; c <= j + 1; c++ ){
            outAry[r][c] = this -> structAry[ structRow ][ structCol ];
            structCol++;
        }
        structCol = 0;
        structRow++;
    }

}
```

aryToFile

```
void aryToFile(int **ary, ofstream &outFile ){
    outFile << this -> numImgRows << " " << this -> numImgCols << " " << this -> imgMin << " " << this -> imgMax << endl;
    for( int i = this -> rowFrameSize; i < this -> rowSize; i++ ){
        for( int j = this -> colFrameSize; j < this -> colSize; j++ ){
            outFile << ary[i][j] << " ";
        }
        outFile << endl;
    }
}
```

prettyPrint

```
void prettyPrint( int **ary,  ofstream &outFile){
    if(ary == this -> structAry){
        outFile << "Structure Element" << endl;
        for( int i = 0; i < this -> numStructRows; i++ ){
            for( int j = 0; j < this -> numStructCols; j++ ){
                if(ary[i][j] == 0) outFile << ". ";
                else outFile << ary[i][j] << " ";
            }
            outFile << endl;
        }
    }else{
        string msg[5] = {"Zero Framed", "Dilation", "Erosion", "Opening", "Closing"};
        outFile << msg[this -> msgCounter] << endl;
        this -> msgCounter++;

        for( int i = 0; i < this -> rowSize; i++ ){
            for( int j = 0; j < this -> colSize; j++ ){
                if(ary[i][j] == 0) outFile << ". ";
                else outFile << ary[i][j] << " ";
            }
            outFile << endl;
        }
    }
}
```

Test 1

dilateOutFile

```
35 60 0 1
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 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
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```

erodeOutFile

```
35 60 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 0 0 0 0 0 0 0 0 0 0 0 0 0
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openingOutFile

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closingOutFile

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prettyPrintFile

Zero Framed

Structure Element

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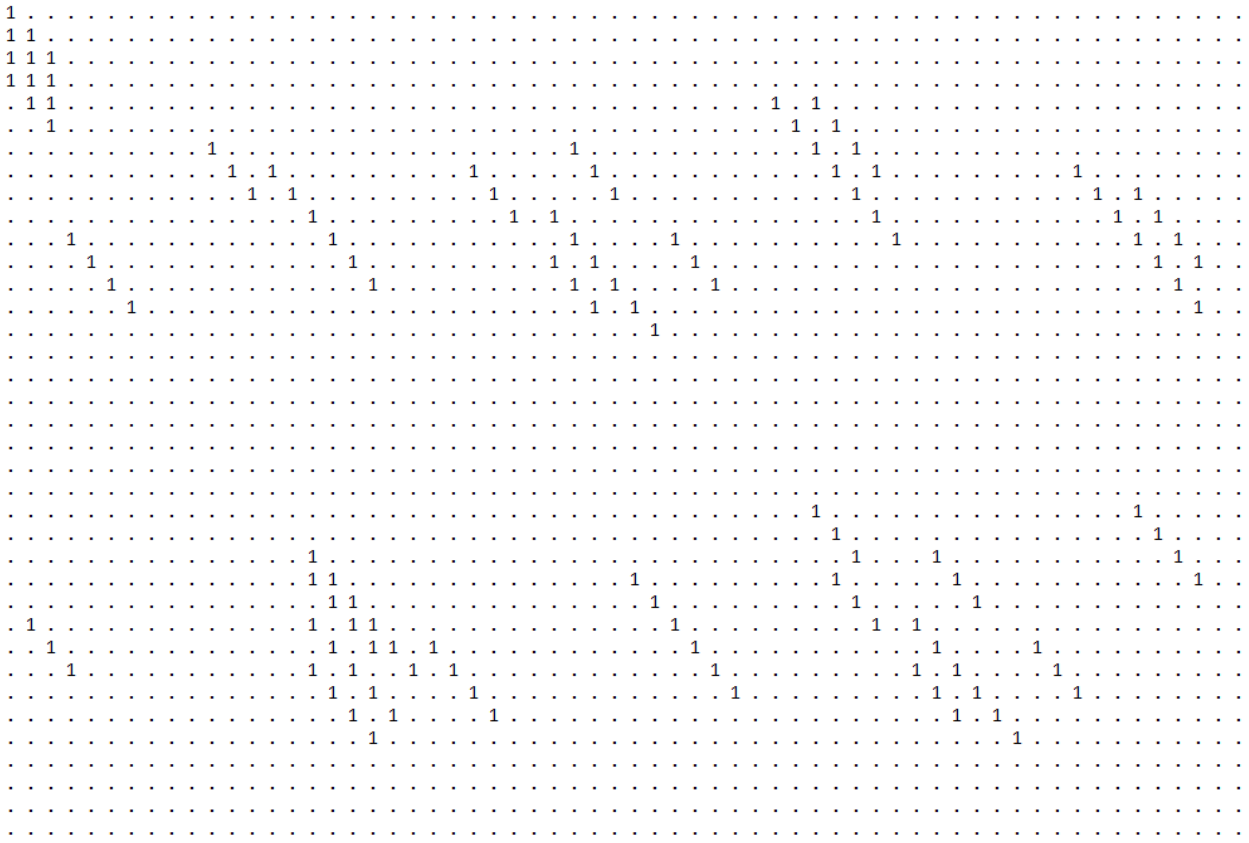
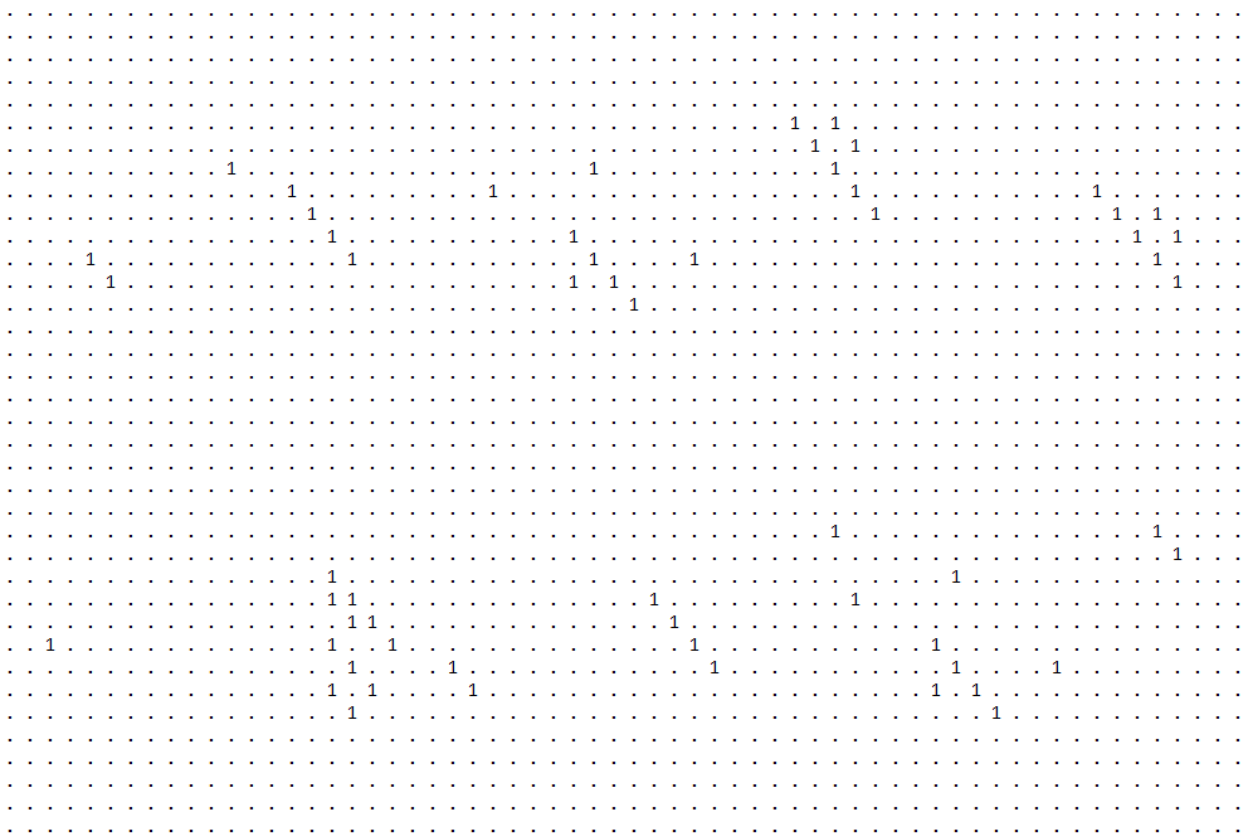
Dilation

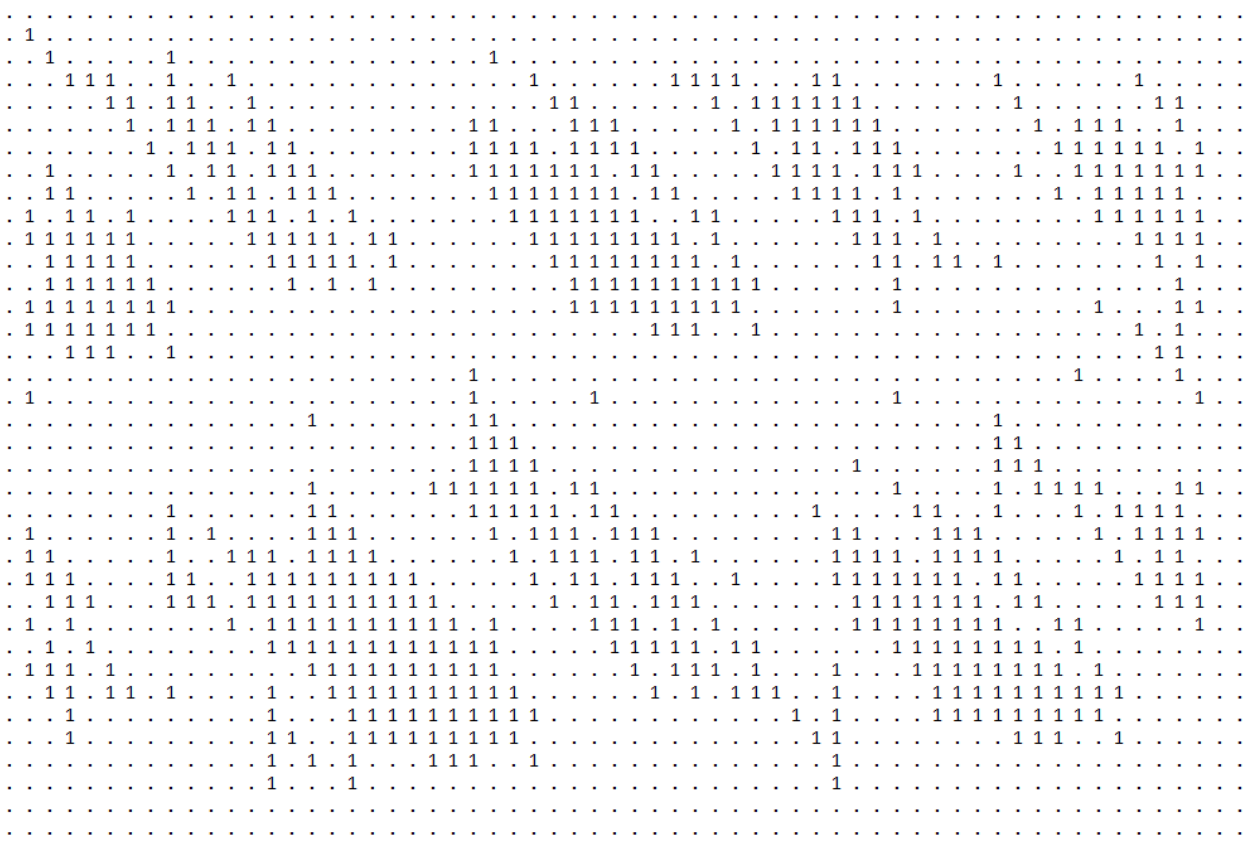
Opening



Erosion



Closing



Test 2

closingOutfile

dilateOutFile

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erodeOutFile

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openingOutFile

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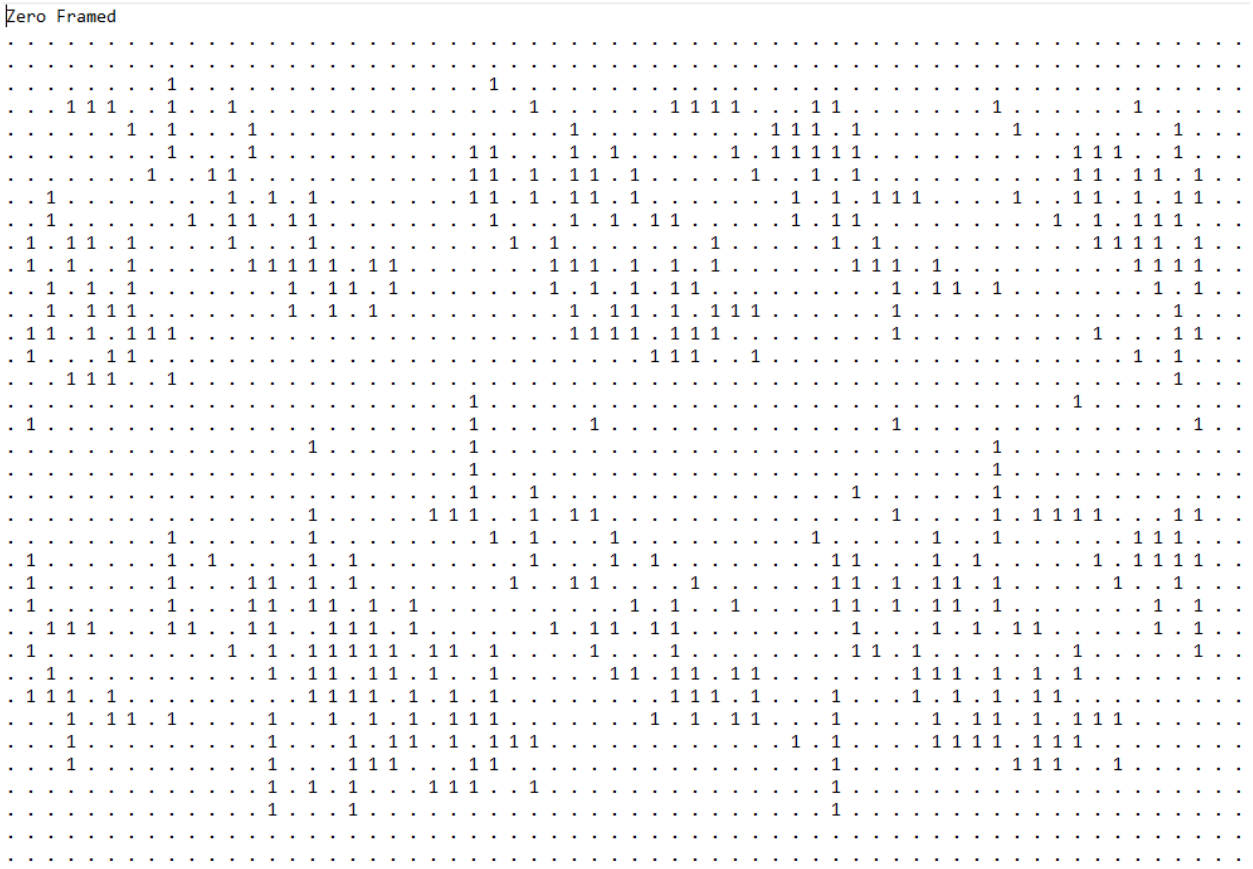
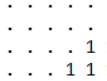
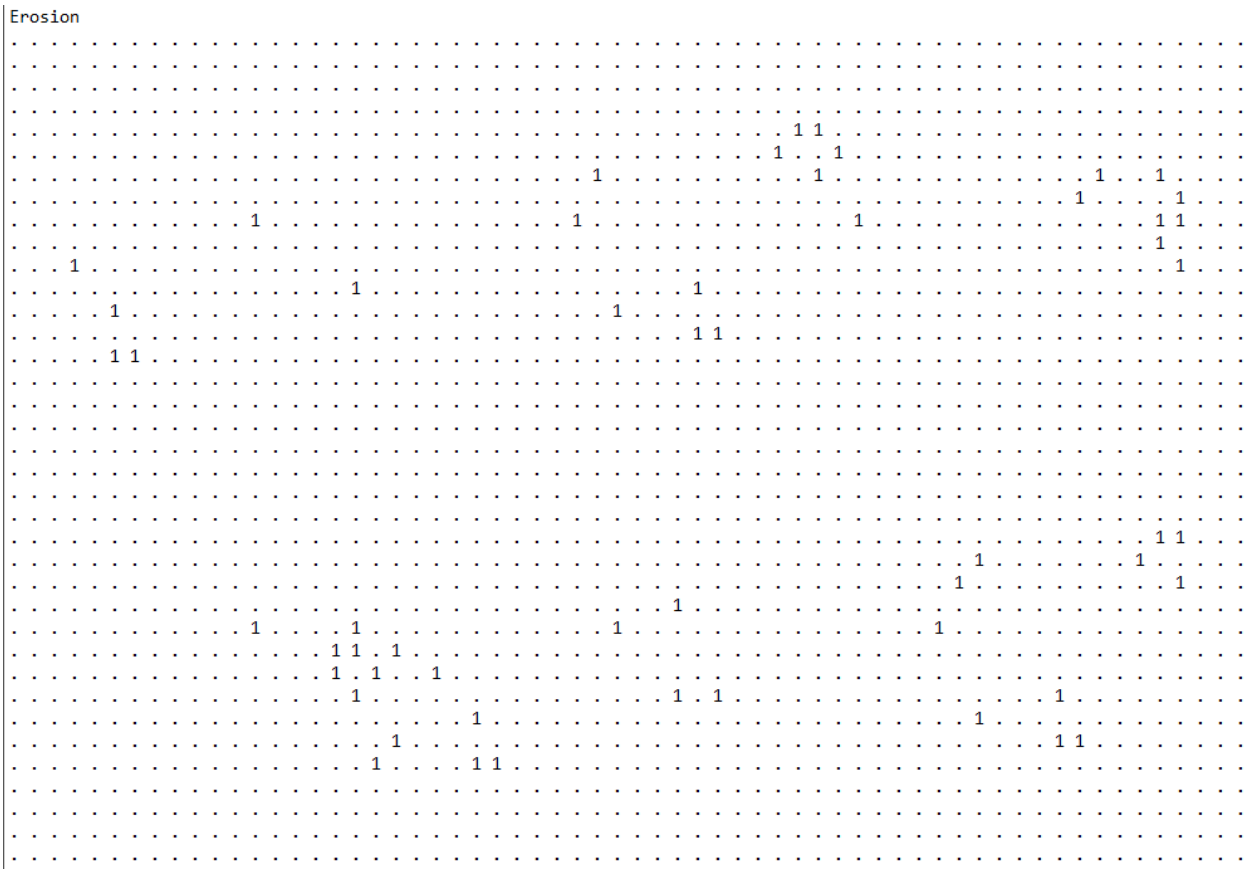
prettyPrintFile



Structure Element



Dilation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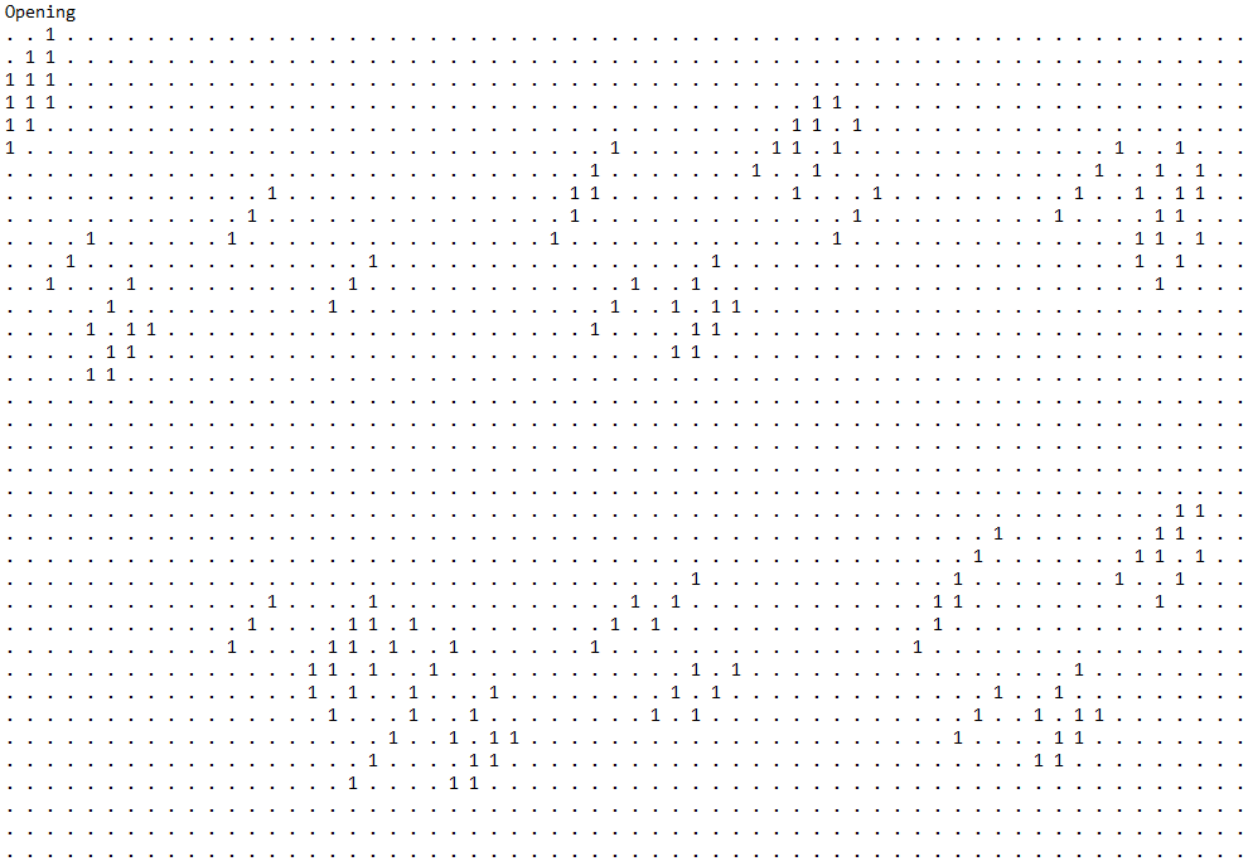
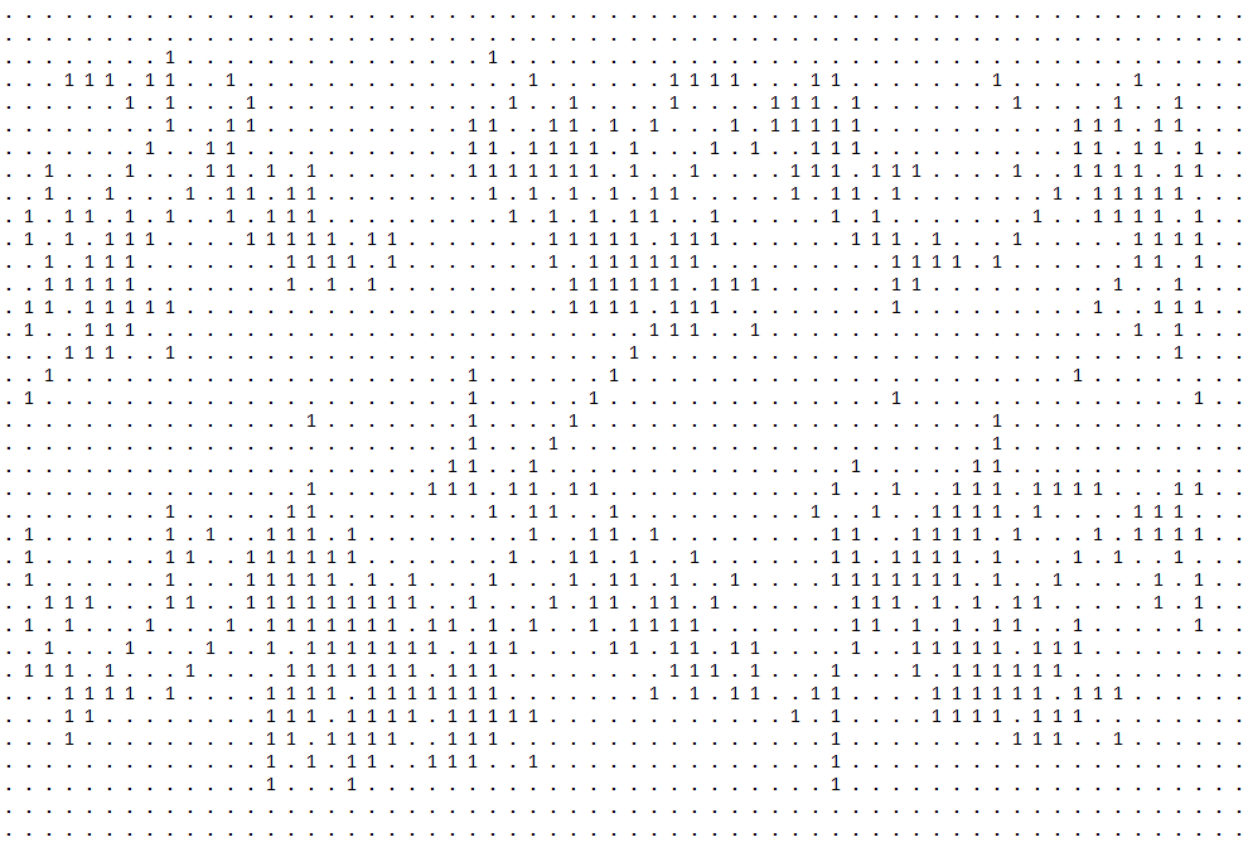

Opening

Closing



Test 3

closingOutFile

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dilateOutFile

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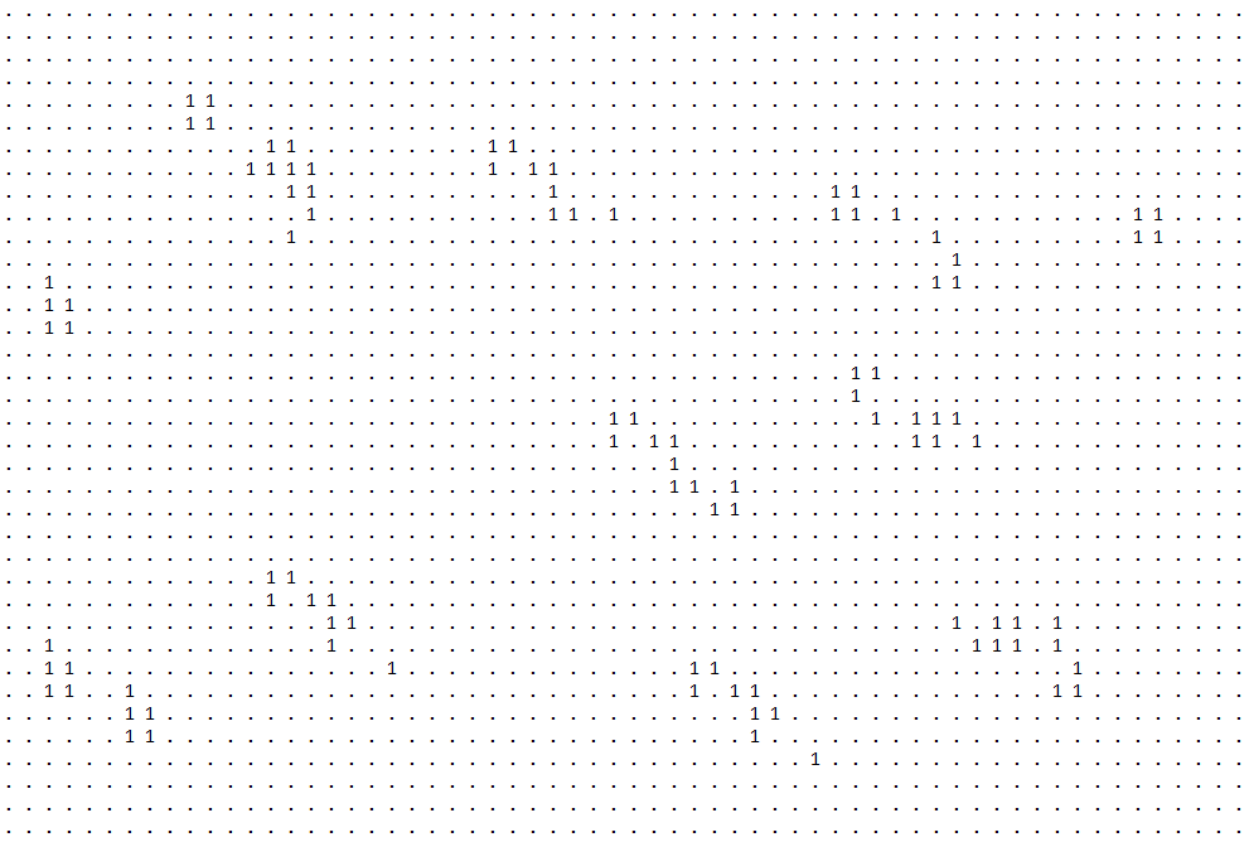

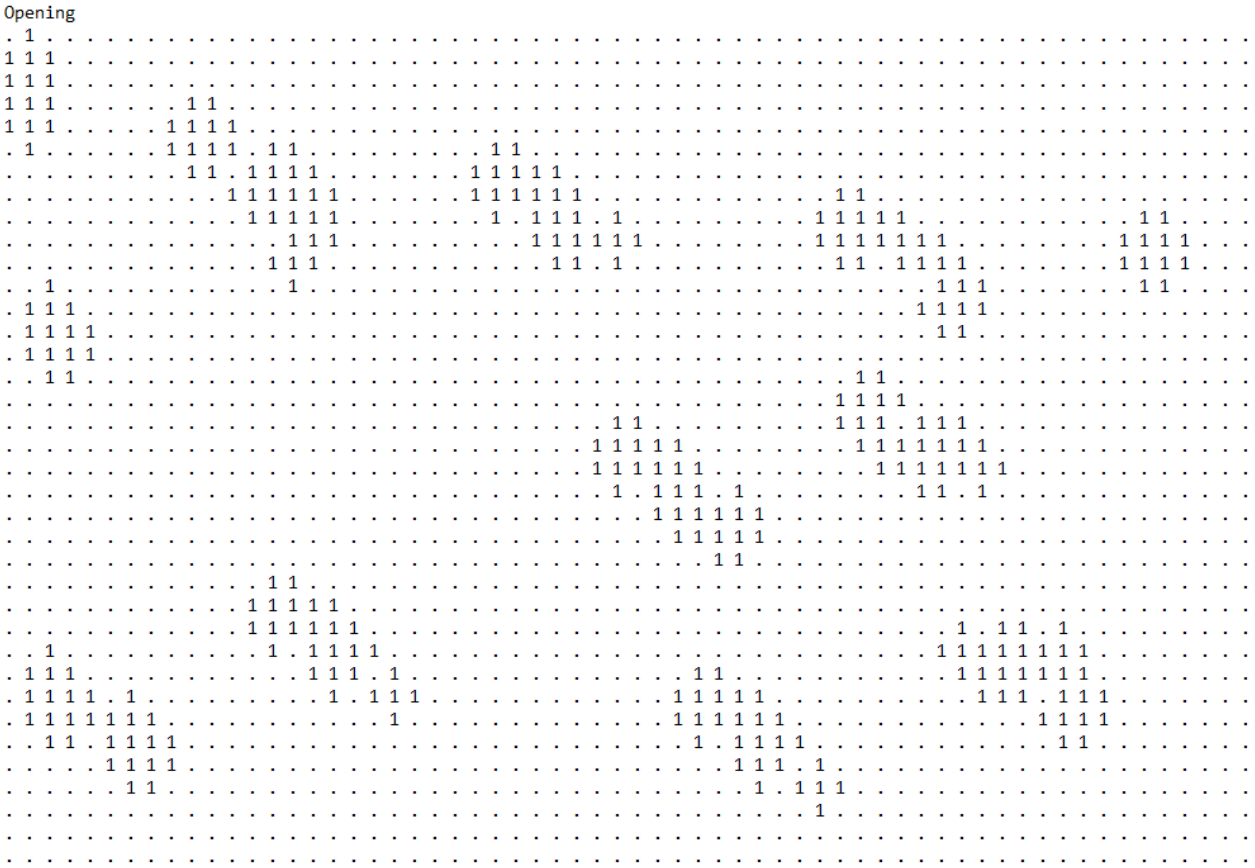
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prettyPrintfile

Structure Element

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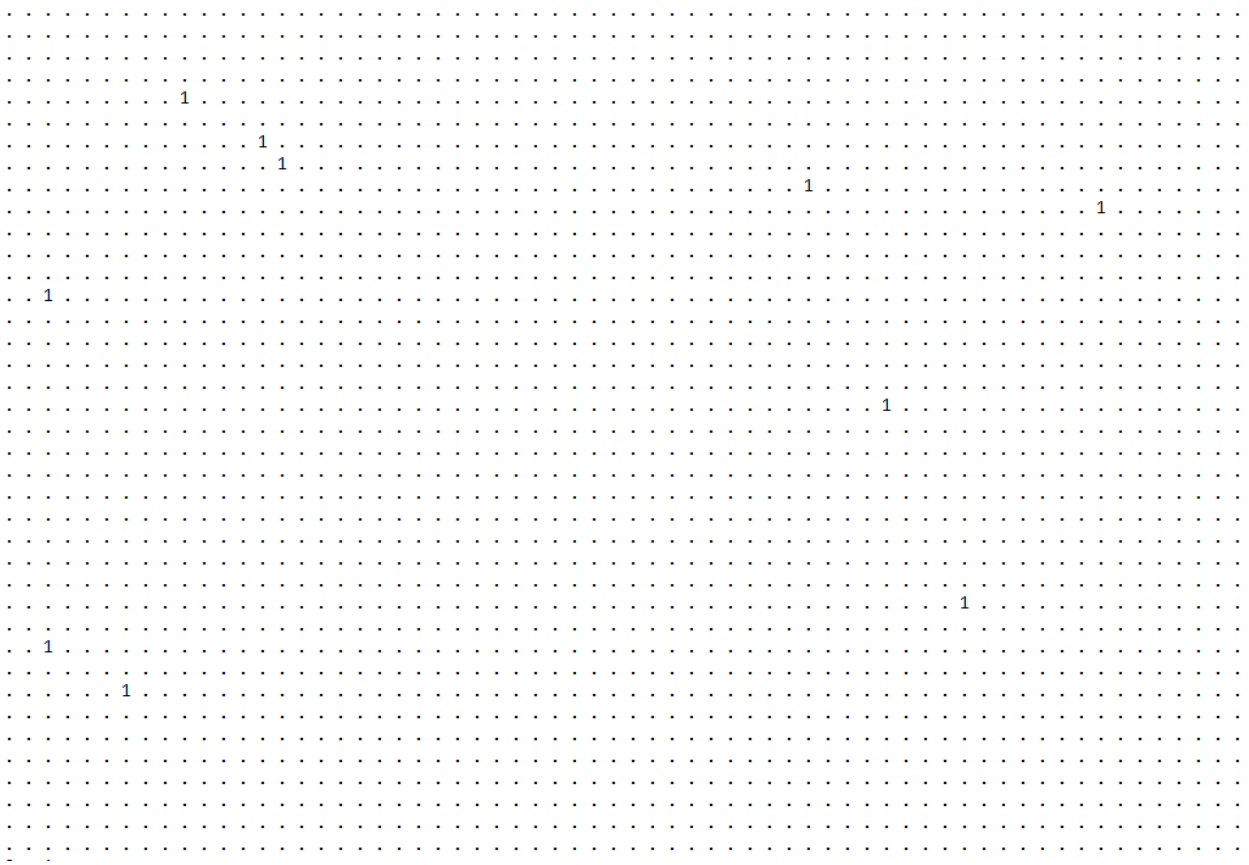
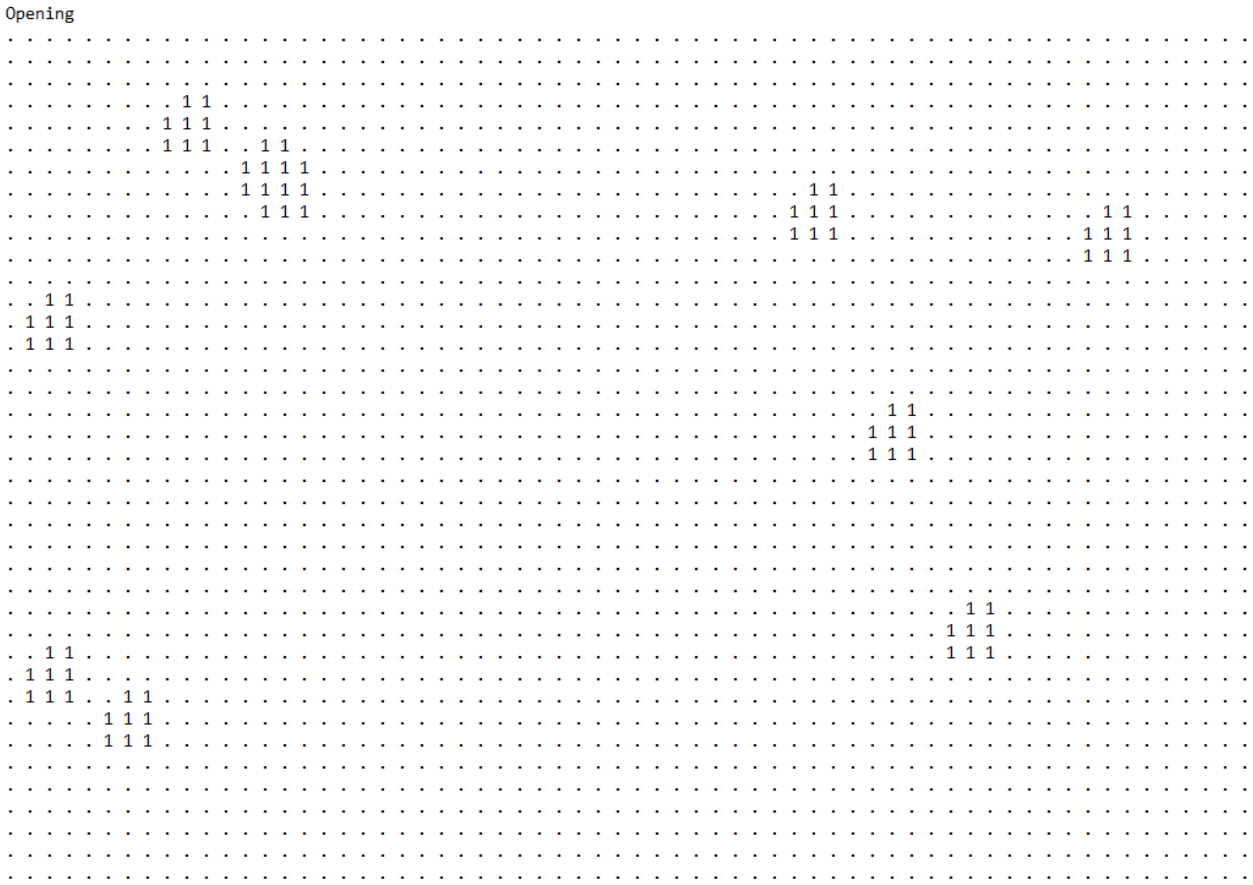
1 1 1 1
. 1 1 .

Dilation

Erosion




Opening

Closing