LAB 2 REPORT – Aaron Bruner

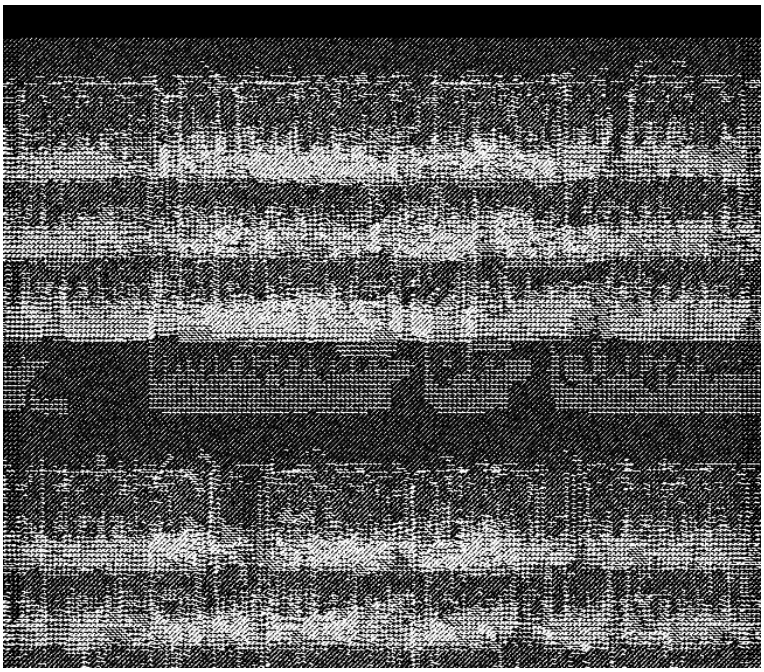
The purpose of this lab was to detect the location of characters in an image. The lab instructions laid out 4 steps for us to follow. The first step was to read the input image, template image, and ground truth files.

```
./lab2
Step 1:
Performing matched filter on images [parenthood.ppm] and [parenthood_e_template.ppm] using ground
truth [parenthood_gt.txt]
        * Reading in source image...    [SUCCESS]
        * Reading in template image...  [SUCCESS]
        * Opening ground truth file...  [SUCCESS]
        * Found 1261 number of rows in the ground truth file
        * Allocating space for ground truth file... [SUCCESS]
        * Scanning in values from ground truth file...  [Read in 1261 rows]
```

The above text is the first step output from the terminal when we execute out code. As we can see, the files parenthood.ppm, parenthood_e_template.ppm and parenthood_gt.txt are used since command line arguments were not provided. We have the option of specifying which files we want to use by using the following command: ./lab2 (sourceFile.ppm) (templateFile.ppm) (groundTruth.txt). We can see that 1261 rows were read in from the ground truth and all files were successfully opened and read in.

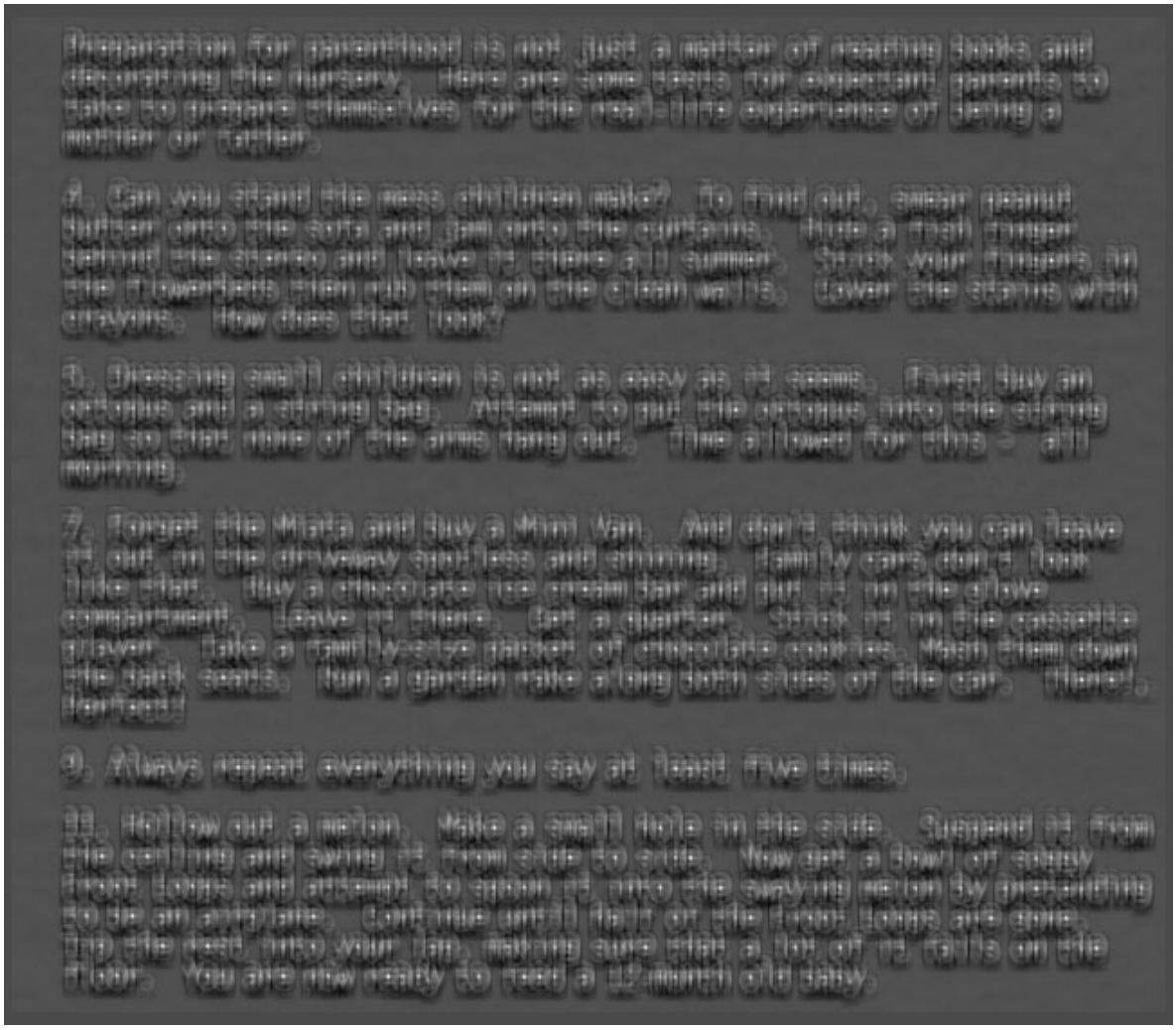
Step 2 asked us to calculate the matched-spatial filter (MSF) image. Below is the output from the terminal and the MSF image.

```
Step 2:
Calculate the mean of the template image...
        * Mean pixel value in the template image = 165
        * Generating the zero mean template image
                * Allocating space for template MSF image...    [SUCCESS]
                * Allocating space for MSF image...     [SUCCESS]
                * Convolving source and zero-mean centered image...     [SUCCESS]
```



Step 3 asked us to normalize the MSF image to 8-bits. Below is the output from the terminal and the normalized image.

```
Step 3:
Finding the minimum pixel and maximum pixel of the MSF...
        * Calculating the minimum and maximum pixel in MSF image...     [SUCCESS]
                * Minimum determined to be: -128215
                * Maximum determined to be: 309645
        * Normalizing the MSF image to 8-bit...
                * Creating space for normalized image...        [SUCCESS]
```

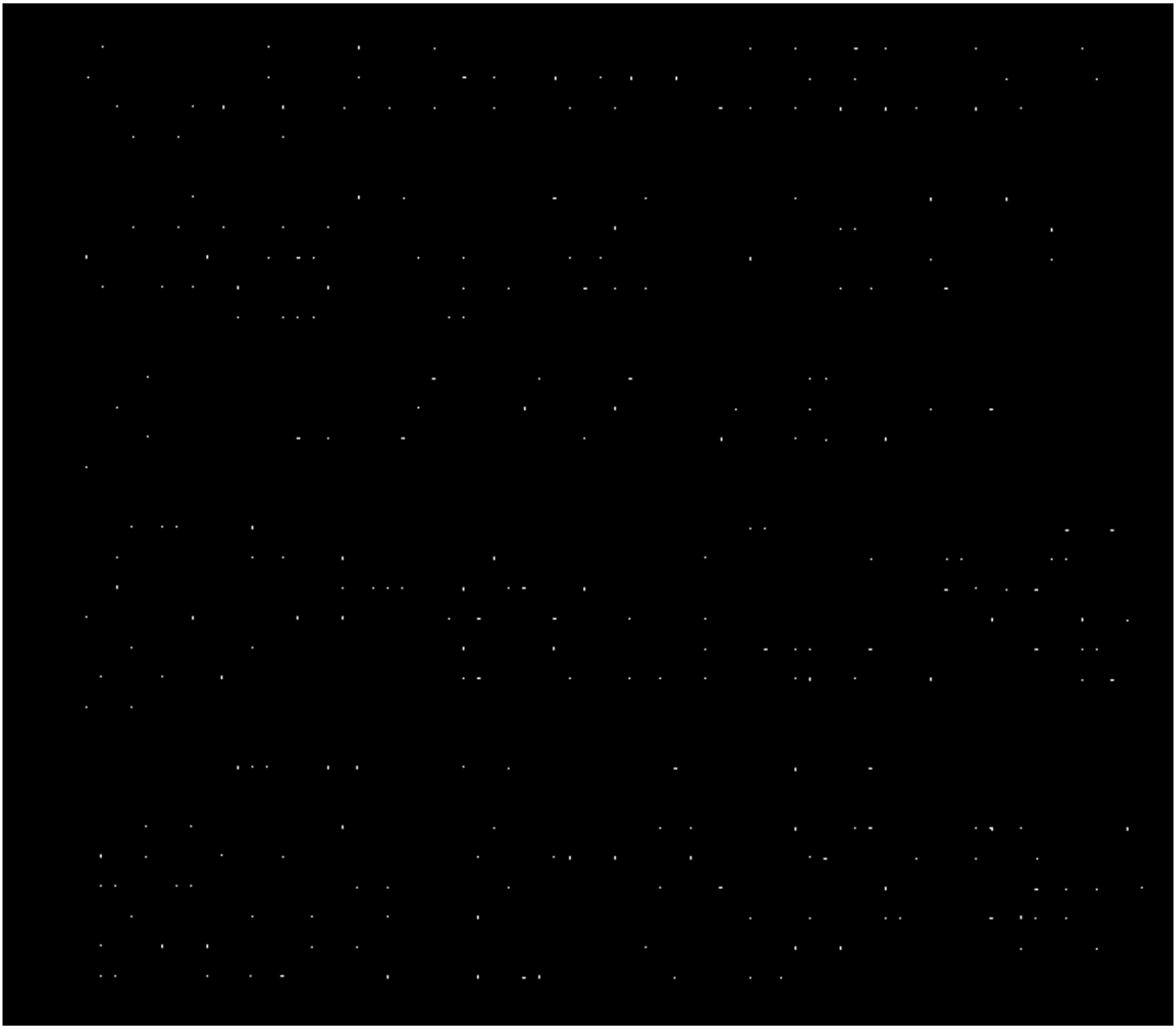


The pixel values with values closer to 255 are more likely to be e.

Step 4 has us thresholding the above image for ranging values of T. The ideal value of T was determined to be 200 which yields the highest number of e's with the lowest number of FP.

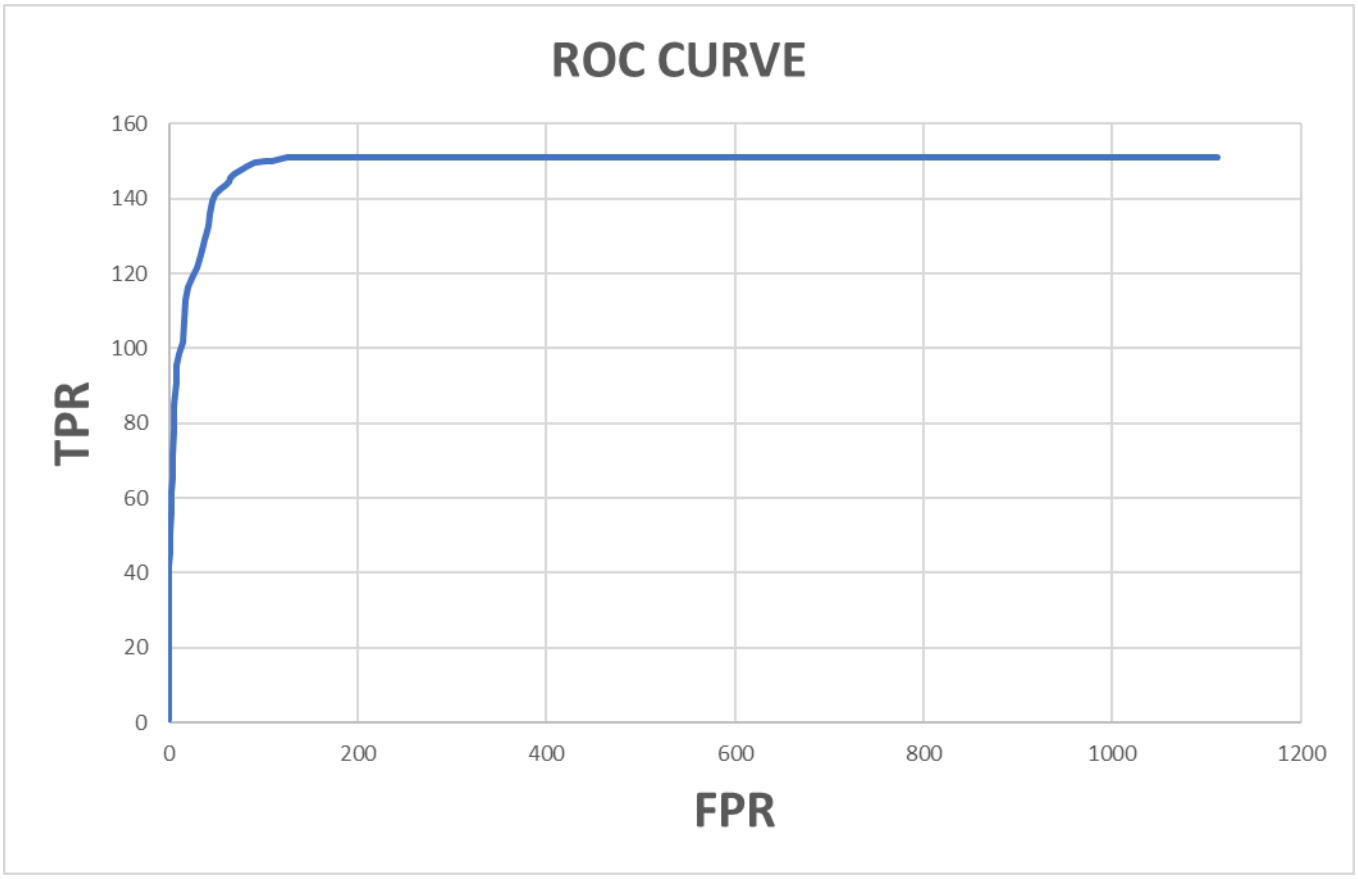
```
Step 4:
Creating a binary image using the threshold...
        * Allocating space for result image     [SUCCESS]
        * Loop over the MSF image with threshold values from 0 to 255 incrementing by 10...
        * Generating the ideal OCR image using threshold value [200]... [SUCCESS]
        * Sending result image to idealImage.ppm...     [SUCCESS]
```

The full output of TP and FP values for T values ranging from 0 to 255 are on the next page along with the ideal output image at 200.



Threshold [0] : TP = 151 | FP = 1111
Threshold [1] : TP = 151 | FP = 1111
Threshold [2] : TP = 151 | FP = 1111
Threshold [3] : TP = 151 | FP = 1111
Threshold [4] : TP = 151 | FP = 1111
Threshold [5] : TP = 151 | FP = 1111
Threshold [6] : TP = 151 | FP = 1111
Threshold [7] : TP = 151 | FP = 1111
Threshold [8] : TP = 151 | FP = 1111
Threshold [9] : TP = 151 | FP = 1111
Threshold [10] : TP = 151 | FP = 1111
Threshold [11] : TP = 151 | FP = 1111
Threshold [12] : TP = 151 | FP = 1111
Threshold [13] : TP = 151 | FP = 1111
Threshold [14] : TP = 151 | FP = 1111
Threshold [15] : TP = 151 | FP = 1111
Threshold [16] : TP = 151 | FP = 1111
Threshold [17] : TP = 151 | FP = 1111
Threshold [18] : TP = 151 | FP = 1111
Threshold [19] : TP = 151 | FP = 1111
Threshold [20] : TP = 151 | FP = 1111
Threshold [21] : TP = 151 | FP = 1111
Threshold [22] : TP = 151 | FP = 1111
Threshold [23] : TP = 151 | FP = 1111
Threshold [24] : TP = 151 | FP = 1111
Threshold [25] : TP = 151 | FP = 1111
Threshold [26] : TP = 151 | FP = 1111
Threshold [27] : TP = 151 | FP = 1111
Threshold [28] : TP = 151 | FP = 1111
Threshold [29] : TP = 151 | FP = 1111
Threshold [30] : TP = 151 | FP = 1111
Threshold [31] : TP = 151 | FP = 1111
Threshold [32] : TP = 151 | FP = 1111
Threshold [33] : TP = 151 | FP = 1111
Threshold [34] : TP = 151 | FP = 1111
Threshold [35] : TP = 151 | FP = 1111
Threshold [36] : TP = 151 | FP = 1111
Threshold [37] : TP = 151 | FP = 1111
Threshold [38] : TP = 151 | FP = 1111
Threshold [39] : TP = 151 | FP = 1111
Threshold [40] : TP = 151 | FP = 1111
Threshold [41] : TP = 151 | FP = 1111
Threshold [42] : TP = 151 | FP = 1111
Threshold [43] : TP = 151 | FP = 1111
Threshold [44] : TP = 151 | FP = 1111
Threshold [45] : TP = 151 | FP = 1111
Threshold [46] : TP = 151 | FP = 1111
Threshold [47] : TP = 151 | FP = 1111
Threshold [48] : TP = 151 | FP = 1111
Threshold [49] : TP = 151 | FP = 1111
Threshold [50] : TP = 151 | FP = 1111
Threshold [51] : TP = 151 | FP = 1111
Threshold [52] : TP = 151 | FP = 1111
Threshold [53] : TP = 151 | FP = 1111
Threshold [54] : TP = 151 | FP = 1111
Threshold [55] : TP = 151 | FP = 1111
Threshold [56] : TP = 151 | FP = 1111
Threshold [57] : TP = 151 | FP = 1111
Threshold [58] : TP = 151 | FP = 1111
Threshold [59] : TP = 151 | FP = 1111
Threshold [60] : TP = 151 | FP = 1111
Threshold [61] : TP = 151 | FP = 1111
Threshold [62] : TP = 151 | FP = 1111
Threshold [63] : TP = 151 | FP = 1111
Threshold [64] : TP = 151 | FP = 1111
Threshold [65] : TP = 151 | FP = 1111
Threshold [66] : TP = 151 | FP = 1111
Threshold [67] : TP = 151 | FP = 1111
Threshold [68] : TP = 151 | FP = 1111
Threshold [69] : TP = 151 | FP = 1111
Threshold [70] : TP = 151 | FP = 1111
Threshold [71] : TP = 151 | FP = 1111
Threshold [72] : TP = 151 | FP = 1111
Threshold [73] : TP = 151 | FP = 1111
Threshold [74] : TP = 151 | FP = 1111

Threshold [75] : TP = 151 | FP = 1111
Threshold [76] : TP = 151 | FP = 1111
Threshold [77] : TP = 151 | FP = 1111
Threshold [78] : TP = 151 | FP = 1111
Threshold [79] : TP = 151 | FP = 1111
Threshold [80] : TP = 151 | FP = 1111
Threshold [81] : TP = 151 | FP = 1111
Threshold [82] : TP = 151 | FP = 1111
Threshold [83] : TP = 151 | FP = 1111
Threshold [84] : TP = 151 | FP = 1111
Threshold [85] : TP = 151 | FP = 1111
Threshold [86] : TP = 151 | FP = 1111
Threshold [87] : TP = 151 | FP = 1111
Threshold [88] : TP = 151 | FP = 1111
Threshold [89] : TP = 151 | FP = 1111
Threshold [90] : TP = 151 | FP = 1111
Threshold [91] : TP = 151 | FP = 1111
Threshold [92] : TP = 151 | FP = 1111
Threshold [93] : TP = 151 | FP = 1111
Threshold [94] : TP = 151 | FP = 1111
Threshold [95] : TP = 151 | FP = 1111
Threshold [96] : TP = 151 | FP = 1111
Threshold [97] : TP = 151 | FP = 1111
Threshold [98] : TP = 151 | FP = 1111
Threshold [99] : TP = 151 | FP = 1111
Threshold [100] : TP = 151| FP = 1111
Threshold [101] : TP = 151| FP = 1111
Threshold [102] : TP = 151| FP = 1111
Threshold [103] : TP = 151| FP = 1111
Threshold [104] : TP = 151| FP = 1111
Threshold [105] : TP = 151| FP = 1111
Threshold [106] : TP = 151| FP = 1111
Threshold [107] : TP = 151| FP = 1111
Threshold [108] : TP = 151| FP = 1110
Threshold [109] : TP = 151| FP = 1110
Threshold [110] : TP = 151| FP = 1110
Threshold [111] : TP = 151| FP = 1110
Threshold [112] : TP = 151| FP = 1109
Threshold [113] : TP = 151| FP = 1109
Threshold [114] : TP = 151| FP = 1108
Threshold [115] : TP = 151| FP = 1107
Threshold [116] : TP = 151| FP = 1106
Threshold [117] : TP = 151| FP = 1105
Threshold [118] : TP = 151| FP = 1105
Threshold [119] : TP = 151| FP = 1102
Threshold [120] : TP = 151| FP = 1101
Threshold [121] : TP = 151| FP = 1097
Threshold [122] : TP = 151| FP = 1097
Threshold [123] : TP = 151| FP = 1096
Threshold [124] : TP = 151| FP = 1096
Threshold [125] : TP = 151| FP = 1094
Threshold [126] : TP = 151| FP = 1091
Threshold [127] : TP = 151| FP = 1088
Threshold [128] : TP = 151| FP = 1084
Threshold [129] : TP = 151| FP = 1079
Threshold [130] : TP = 151| FP = 1073
Threshold [131] : TP = 151| FP = 1068
Threshold [132] : TP = 151| FP = 1066
Threshold [133] : TP = 151| FP = 1058
Threshold [134] : TP = 151| FP = 1053
Threshold [135] : TP = 151| FP = 1047
Threshold [136] : TP = 151| FP = 1041
Threshold [137] : TP = 151| FP = 1035
Threshold [138] : TP = 151| FP = 1026
Threshold [139] : TP = 151| FP = 1016
Threshold [140] : TP = 151| FP = 1010
Threshold [141] : TP = 151| FP = 1003
Threshold [142] : TP = 151| FP = 994
Threshold [143] : TP = 151| FP = 984
Threshold [144] : TP = 151| FP = 971
Threshold [145] : TP = 151| FP = 957
Threshold [146] : TP = 151| FP = 947
Threshold [147] : TP = 151| FP = 929
Threshold [148] : TP = 151| FP = 921
Threshold [149] : TP = 151| FP = 908
Threshold [150] : TP = 151| FP = 889
Threshold [151] : TP = 151| FP = 873
Threshold [152] : TP = 151| FP = 849
Threshold [153] : TP = 151| FP = 830
Threshold [154] : TP = 151| FP = 809
Threshold [155] : TP = 151| FP = 791
Threshold [156] : TP = 151| FP = 767
Threshold [157] : TP = 151| FP = 746
Threshold [158] : TP = 151| FP = 726
Threshold [159] : TP = 151| FP = 699
Threshold [160] : TP = 151| FP = 675
Threshold [161] : TP = 151| FP = 656
Threshold [162] : TP = 151| FP = 643
Threshold [163] : TP = 151| FP = 624
Threshold [164] : TP = 151| FP = 612
Threshold [165] : TP = 151| FP = 597
Threshold [166] : TP = 151| FP = 580
Threshold [167] : TP = 151| FP = 565
Threshold [168] : TP = 151| FP = 554
Threshold [169] : TP = 151| FP = 544
Threshold [170] : TP = 151| FP = 535
Threshold [171] : TP = 151| FP = 519
Threshold [172] : TP = 151| FP = 509
Threshold [173] : TP = 151| FP = 492
Threshold [174] : TP = 151| FP = 477
Threshold [175] : TP = 151| FP = 468
Threshold [176] : TP = 151| FP = 450
Threshold [177] : TP = 151| FP = 440
Threshold [178] : TP = 151| FP = 421
Threshold [179] : TP = 151| FP = 400
Threshold [180] : TP = 151| FP = 386
Threshold [181] : TP = 151| FP = 372
Threshold [182] : TP = 151| FP = 349
Threshold [183] : TP = 151| FP = 339
Threshold [184] : TP = 151| FP = 319
Threshold [185] : TP = 151| FP = 308
Threshold [186] : TP = 151| FP = 292
Threshold [187] : TP = 151| FP = 283
Threshold [188] : TP = 151| FP = 272
Threshold [189] : TP = 151| FP = 253
Threshold [190] : TP = 151| FP = 231
Threshold [191] : TP = 151| FP = 215
Threshold [192] : TP = 151| FP = 200
Threshold [193] : TP = 151| FP = 187
Threshold [194] : TP = 151| FP = 180
Threshold [195] : TP = 151| FP = 169
Threshold [196] : TP = 151| FP = 162
Threshold [197] : TP = 151| FP = 148
Threshold [198] : TP = 151| FP = 141
Threshold [199] : TP = 151| FP = 133
Threshold [200] : TP = 151| FP = 124
Threshold [201] : TP = 150| FP = 113
Threshold [202] : TP = 150| FP = 108
Threshold [203] : TP = 150| FP = 101
Threshold [204] : TP = 149| FP = 90
Threshold [205] : TP = 148| FP = 82
Threshold [206] : TP = 147| FP = 75
Threshold [207] : TP = 146| FP = 69
Threshold [208] : TP = 145| FP = 65
Threshold [209] : TP = 144| FP = 64
Threshold [210] : TP = 143| FP = 59
Threshold [211] : TP = 142| FP = 54
Threshold [212] : TP = 142| FP = 52
Threshold [213] : TP = 140| FP = 48
Threshold [214] : TP = 139| FP = 45
Threshold [215] : TP = 133| FP = 43
Threshold [216] : TP = 133| FP = 42
Threshold [217] : TP = 130| FP = 40
Threshold [218] : TP = 128| FP = 37
Threshold [219] : TP = 122| FP = 34
Threshold [220] : TP = 121| FP = 30
Threshold [221] : TP = 118| FP = 25
Threshold [222] : TP = 115| FP = 20
Threshold [223] : TP = 111| FP = 17
Threshold [224] : TP = 104| FP = 16
Threshold [225] : TP = 99 | FP = 14
Threshold [226] : TP = 98 | FP = 10
Threshold [227] : TP = 93 | FP = 7
Threshold [228] : TP = 89 | FP = 7
Threshold [229] : TP = 81 | FP = 5
Threshold [230] : TP = 75 | FP = 5
Threshold [231] : TP = 68 | FP = 4
Threshold [232] : TP = 63 | FP = 4
Threshold [233] : TP = 60 | FP = 2
Threshold [234] : TP = 53 | FP = 2
Threshold [235] : TP = 48 | FP = 1
Threshold [236] : TP = 43 | FP = 1
Threshold [237] : TP = 41 | FP = 0
Threshold [238] : TP = 39 | FP = 0
Threshold [239] : TP = 35 | FP = 0
Threshold [240] : TP = 31 | FP = 0
Threshold [241] : TP = 28 | FP = 0
Threshold [242] : TP = 24 | FP = 0
Threshold [243] : TP = 23 | FP = 0
Threshold [244] : TP = 20 | FP = 0
Threshold [245] : TP = 16 | FP = 0
Threshold [246] : TP = 13 | FP = 0
Threshold [247] : TP = 11 | FP = 0
Threshold [248] : TP = 8 | FP = 0
Threshold [249] : TP = 6 | FP = 0
Threshold [250] : TP = 5 | FP = 0
Threshold [251] : TP = 1 | FP = 0
Threshold [252] : TP = 1 | FP = 0
Threshold [253] : TP = 1 | FP = 0
Threshold [254] : TP = 1 | FP = 0
Threshold [255] : TP = 1 | FP = 0


ROC CURVE
TPR
FPR
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200

Source Code:

```
/* File  : lab2.c
   Author: Aaron Bruner
   Class : ECE - 4310 : Introduction to Computer Vision
   Term  : Fall 2022

   Description: The purpose of this lab was to design and implement a matched filter (normalized
cross-correlation) to recognize letters in an image of text.
                The ground truth file lists all the letters and image pixel coordinates of text in
the image. The pixel coordinates are for the center point of each letter.

   Required Files:
    * parenthood.ppm
    * parenthood_e_template.ppm
    * parenthood_gt.txt

   Bugs:
    * Currently none
*/

#define True 1
#define False 0
#define DEBUG False
#define T 255 // Upper limit for thresholding

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>

struct groundTruth {
    char letter;
    int  x; // COLUMN
    int  y; // ROW
};

unsigned char* readImage( int* ROWS, int* COLS, char* source);
unsigned char* createImage(int size);

char* sourceImageDir    = "parenthood.ppm";
char* templateImageDir  = "parenthood_e_template.ppm";
char* groundTruthDir    = "parenthood_gt.txt";

int main(int argc, char* argv[])
{
    unsigned char* sourceImage, *templateImage, *zeroMeanImage, *MSF_Normalized, *thresholdImage;
    int* templateMSF, *MSF;
    struct groundTruth* truth;
    char sourceHeader[320], templateHeader[320], temp, letter;
    int temp1, temp2, fileRows = 0; // Number of rows in the ground truth file
    int i = 0, j = 0, mean = 0, sourceROWS, sourceCOLS, templateROWS, templateCOLS, filterRow,
filterCol;
    int r, c, dr, dc, wr, wc, average, min, max, found = False, TP, FP, maxTP, maxT;
    FILE* fpt, *TPFPfpt;

    /* ──────────────────────────────────────────────────────────────────────────────────────
*/
    /*                      STEP 1: Read in source, template and ground truth
*/
    /*      * User provides no arguments (argc == 1) then we default to specified files
*/
```

```
    /*      * User provides 4 arguments  (argc == 4) then we open provided files
*/
    /* ----------------------------------------------------------------------------
*/

    printf("Step 1:\n");
    if (argc == 1) {
        printf("Performing matched filter on images [%s] and [%s] using ground truth [%s]\n",
sourceImageDir, templateImageDir, groundTruthDir);

        printf("\t* Reading in source image...");
        sourceImage = readImage(&sourceROWS, &sourceCOLS, sourceImageDir);
printf("\t[SUCCESS]\n");
        printf("\t* Reading in template image...");
        templateImage = readImage(&templateROWS, &templateCOLS, templateImageDir);
printf("\t[SUCCESS]\n");

        // Read in CSV/TXT file
        printf("\t* Opening ground truth file...");
        fpt = fopen(groundTruthDir, "r");
        fpt == NULL ? printf("Failed to open %s\n", groundTruthDir), exit(0) :
printf("\t[SUCCESS]\n");
    }
    else if (argc == 4)
    {
        printf("Performing matched filter on images [%s] and [%s] using ground truth [%s]\n",
argv[1], argv[2], argv[3]);

        printf("\t* Reading in source image...");
        sourceImage = readImage(&sourceROWS, &sourceCOLS, argv[1]); printf("\t[SUCCESS]\n");
        printf("\t* Reading in template image...");
        templateImage = readImage(&templateROWS, &templateCOLS, argv[2]); printf("\t[SUCCESS]\n");

        // Read in CSV/TXT file
        printf("\t* Opening ground truth file...");
        fpt = fopen(argv[3], "r");
        fpt == NULL ? printf("Failed to open %s\n", argv[3]), exit(0) : printf("\t[SUCCESS]\n");
    }
    else
    {
        printf("Incorrect number of arguments...\nUsage: ./lab2 (sourceImage.ppm)
(templateImage.ppm) (groundTruth.txt)\n");
        exit(0);
    }

    while ((i = fscanf(fpt, "%c %d %d\n", &temp, &temp1, &temp2)) && !feof(fpt))
        if (i == 3) fileRows += 1;
    printf("\t* Found %d number of rows in the ground truth file\n", fileRows);

    printf("\t* Allocating space for ground truth file...");
    truth = calloc(fileRows, sizeof(struct groundTruth)); printf("\t[SUCCESS]\n");

    rewind(fpt); // Return to the beginning of the file
    printf("\t* Scanning in values from ground truth file...");
    for (i = 0; i <= fileRows && !feof(fpt); i++)
    {
        fscanf(fpt, "%c %d %d\n", &truth[i].letter, &truth[i].x, &truth[i].y);
    }
    fclose(fpt);
    printf("\t[Read in %d rows]\n", i - 1);
```

```
    /* ---------------------------------------------------------------------------------------------
*/
    /*                  STEP 2: Calculate the matched-spatial filter (MSF) image.
*/
    /*                          a) Zero-Mean Center the template
*/
    /*                          b) Convolve with image
*/
    /* ---------------------------------------------------------------------------------------------
*/

    printf("Step 2:\n"); printf("Calculate the mean of the template image...\n");
    for (i = 0; i < templateCOLS * templateROWS; i++) // Sum all pixels
        mean += templateImage[i];
    mean /= templateCOLS * templateROWS;
    printf("\t* Mean pixel value in the template image = %d\n", mean);

    // Zero Mean Template Image
    printf("\t* Generating the zero mean template image\n");
    printf("\t\t* Allocating space for template MSF image...");
    templateMSF = (int*)calloc(templateCOLS * templateROWS, sizeof(int)); printf("\t[SUCCESS]\n");
    for (i = 0; i < templateCOLS * templateROWS; i++)
        templateMSF[i] = templateImage[i] - mean;

    // MSF[r,c] = SIG(+Wr/2 -> dr=Wr/2) SIG(+Wc/2 -> dc=Wc/2)[ I[r + dr,c + dc] * T[dr + Wr/2,dc +
Wc/2] ]
    printf("\t\t* Allocating space for MSF image...");
    MSF = (int*)calloc(sourceCOLS * sourceROWS, sizeof(int)); printf("\t[SUCCESS]\n");
    printf("\t\t* Convolving source and zero-mean centered image...");
    wr = templateROWS; wc = templateCOLS; dr = wr/2; dc = wc/2;
    for (r = dr; r < sourceROWS - dr; r++)
    {
        for (c = dc; c < sourceCOLS - dc; c++, average = 0)
        {
            for (filterRow = -dr; filterRow < templateROWS - dr; filterRow++)
            {
                for (filterCol = -dc; filterCol < templateCOLS - dc; filterCol++)
                {
                    average += sourceImage[(r + filterRow) * sourceCOLS + (c + filterCol)] *
                            templateMSF[(filterRow + dr) * templateCOLS + (filterCol + dc)];
                }
            }
            MSF[r * sourceCOLS + c] = (int)average;
        }
    }
    printf("\t[SUCCESS]\n");

    /* ---------------------------------------------------------------------------------------------
*/
    /*                        STEP 3: Normalize the MSF image to 8-bit
*/
    /*                          a) Find the min and max of MSF
*/
    /*                          b) Create the 8-bit representation of the MSF
*/
    /* ---------------------------------------------------------------------------------------------
*/

    printf("Step 3:\n"); printf("Finding the minimum pixel and maximum pixel of the MSF...\n");
    min = max = MSF[0];
    printf("\t* Calculating the minimum and maximum pixel in MSF image...");
```

```
    for (i = 1; i < sourceROWS * sourceCOLS; i++)
    {
        if (MSF[i] > max)
            max = MSF[i];
        if (MSF[i] < min)
            min = MSF[i];
    }
    printf("\t[SUCCESS]\n");
    printf("\t\t* Minimum determined to be: %d\n\t\t* Maximum determined to be: %d\n", min, max);
    printf("\t* Normalizing the MSF image to 8-bit...");
    printf("\n\t\t* Creating space for normalized image...");
    MSF_Normalized = createImage(sourceCOLS * sourceROWS);
    printf("\t[SUCCESS]\n");

    for (i = 0; i < sourceROWS * sourceCOLS; i++)
    {
        // https://en.wikipedia.org/wiki/Normalization_(image_processing)
        MSF_Normalized[i] = (MSF[i] - min) * 255 / (max - min);
    }

    /* ---------------------------------------------------------------------------------------
*/
    /*                  STEP 4: Looping through the following steps for a range of T
*/
    /*           a) Threshold at T the normalized MSF image to create a binary image
*/
    /*           b) Loop through the ground truth letter locations
*/
    /*                  i. Check a 9 x 15 pixel area centered at the ground truth location. If
*/
    /*                     any pixel in the MSF image is greater than the threshold, consider
*/
    /*                     the letter “detected”.If none of the pixels in the 9 x 15 area are
*/
    /*                     greater than the threshold, consider the letter “not detected”
*/
    /*           c) Categorize and count the detected letters as FP (“detected” but the letter is
*/
    /*              not ‘e’) and TP (“detected” and the letter is ‘e’)
*/
    /*           d) Output the total FP and TP for each T
*/
    /* ---------------------------------------------------------------------------------------
*/

    printf("Step 4:\n"); printf("Creating a binary image using the threshold...");
    printf("\n\t* Allocating space for result image");
    thresholdImage = createImage(sourceCOLS * sourceROWS); printf("\t[SUCCESS]\n");
    char outStr[20];
    TPFPfpt = fopen("TPFP.txt", "w"); TPFPfpt == NULL ? (printf("Failed to open TPFP.txt.\n"),
exit(0)) : TPFPfpt;

    printf("\t* Loop over the MSF image with threshold values from 0 to %d incrementing by
10...\n", T);
    for (i = 0; i <= T; i++, TP = 0, FP = 0)
    {
        // Part a: Generate binary image using threshold
        for (int pixel = 0; pixel < sourceCOLS * sourceROWS; pixel++)
        {
            thresholdImage[pixel] = MSF_Normalized[pixel] >= i ? (unsigned char)255 : (unsigned
char)0;
```

```
        }

        // Part b: Looping through the ground truth letter locations
        for (j = 0; j <= fileRows; j++, found = False)
        {
            for (filterRow = truth[j].y - dr; filterRow <= truth[j].y + dr; filterRow++)
            {
                for (filterCol = truth[j].x - dc; filterCol <= truth[j].x + dc; filterCol++)
                {
                    // i) found a 255 pixel within a 9x15 area of x,y                        |
Check to see if it's already true
                    found = (thresholdImage[filterRow * sourceCOLS + filterCol] == 255) ? True :
(found == True) ? True : False;
                }
            }
            // Part c: If we find a 255 pixel and it's actually e then TP. Otherwise we find
something that's not e it's a FP
            truth[j].letter == 'e' ? (found == True ? TP++ : TP) : (found == True ? FP++ : FP);
        }
        // Part d: Outputting the total FP and TP for each T value ranging from 0 to 255
        fprintf(TPFPfpt, "Threshold [%3d] : TP = %4d\t| FP = %4d\n", i, TP, FP);

        // Find the threshold that gives us the larges amount of TP
        if (T == 0)
        {
            maxTP = TP;
            maxT = i;
        }
        else if (TP >= maxTP)
        {
            maxTP = TP;
            maxT = i;
        }
    }

    // Generating the ideal image using the threshold value with the most TP
    printf("\t* Generating the ideal OCR image using threshold value [%d]...", maxT);
    for (int pixel = 0; pixel < sourceCOLS * sourceROWS; pixel++)
    {
        thresholdImage[pixel] = MSF_Normalized[pixel] >= maxT ? (unsigned char)255 : (unsigned
char)0;
    }
    printf("\t[SUCCESS]\n");
    printf("\t* Sending result image to idealImage.ppm...");
    fpt = fopen("idealImage.ppm", "w");
    fprintf(fpt, "P5 %d %d 255\n", sourceCOLS, sourceROWS);
    fwrite(thresholdImage, sourceCOLS * sourceROWS, 1, fpt);
    fclose(fpt);
    printf("\t[SUCCESS]\n");

    /* ────────────────────────────────────────────────────────────────────────────────
*/
}

/// <summary>
/// The readImage function is designed to take a file name as the source and reads all of the data
into a new image.
/// </summary>
/// <param name="ROWS"> Number of rows in the source image </param>
/// <param name="COLS"> Number of columns in the source image </param>
/// <param name="source"> File name that we're needing to open and read data from </param>
```

```
/// <returns> The function returns an array of values which makes up our image </returns>
unsigned char* readImage(int* ROWS, int* COLS, char* source)
{
    int BYTES, readHeaderReturn;
    static char header[80];

    // Open image for reading
    FILE *fpt = fopen(source, "rb");
    if (fpt == NULL) {
        printf("Failed to open file (%s) for reading.\n", source);
        exit(0);
    }

    /* read image header (simple 8-bit greyscale PPM only) */
    if (fscanf(fpt, "%s %d %d %d\n", header, &*COLS, &*ROWS, &BYTES) != 4 || strcmp(header, "P5")
!= 0 || BYTES != 255)
    {
        fclose(fpt);
        printf("Image header corrupted.\n");
        exit(0);
    }

    unsigned char* destination = createImage((*ROWS)*(*COLS)); // Create an empty image that is
large enough for ROWS x COLS bytes

    fread(destination, 1, (*ROWS) * (*COLS), fpt);
    fclose(fpt);

    return destination;
}

/// <summary>
/// createImage allocates memory for our image array.
/// </summary>
/// <param name="size"> Number of bytes that are needing to be allocated for our image </param>
/// <returns> An array with 'size' number of bytes allocated for our image use</returns>
unsigned char* createImage(int size)
{
    unsigned char* newImage = (unsigned char*)calloc(size, sizeof(unsigned char));
    if (newImage == NULL) {
        printf("Unable to allocate %d bytes of memory.\n", size);
        exit(0);
    }

    return newImage;
}
```