Introduction to Computer Vision
Template Matching

Mayukh Sattiraju
msattir@clemson.edu

ECE 631
Lab 2 Report

September 24, 2017

1 Introduction

This lab deals with counting the number of occurrences of a particular template (in this case the letter 'e') in an image. Here we employ a Matched Spatial Filter to perform a Template Matching and then analyze a ROC curve to choose the best threshold.

2 Implementation

2.1 Match Spatial Filter

The MSF filter is a 'zero-normalized' version of the input template. This normalized kernel is used to convolve with the input image. The algorithm gives a high response (outputs a large value) when the template matches a window in the input image.

The Mathematical expression for the convolution is given as:

$$MSF[r,c] = \sum_{dr=-Wr/2}^{+Wr/2} \sum_{dc=-Wc/2}^{+Wc/2} [I[r+dr, c+dc] * T[dr+Wr/2, dc+Wc/2]]$$

Where Wc and Wr are the height and width of the template.

Below is a code snippet of the filter implementation on C

Listing 1: MSF C Implementation

```
            /* convolving with image, skipping the border points */
for (r=7; r<ROWS_i-7; r++)
  for (c=4; c<COLS_i-4; c++)
    {
    sum=0;
    for (r2=-7; r2<=7; r2++)
      for (c2=-4; c2<=4; c2++)
        sum+=image[(r+r2)*COLS_i+(c+c2)]*ker1[(r2+7)*COLS_k+(c2+4)];
    smoothed[r*COLS_i+c]=sum;
    }

   // Iterate through MSF image to get MSF min and max values

/* Normalizing the MSF Image */
for (r=7; r<ROWS_i-7; r++)
  for (c=4; c<COLS_i-4; c++)
       smoothed1[r*COLS_i+c]=((smoothed[r*COLS_i+c]-msf_min)/((msf_max-msf_min)*1.0))*255;
```

The convolved image, has a range that is outside 8-bit char (0-255) hence, a normalization is performed to make the minimum of the MSF image 0 and the maximum 255.

This is the original input image and the output MSF Image.

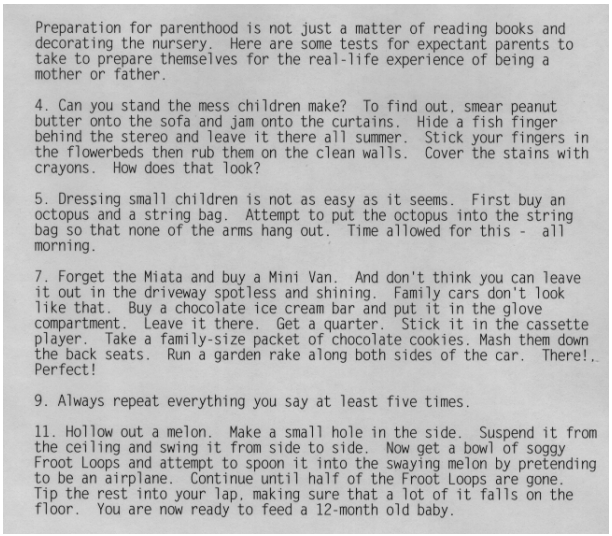

Figure 1: Original Input Image

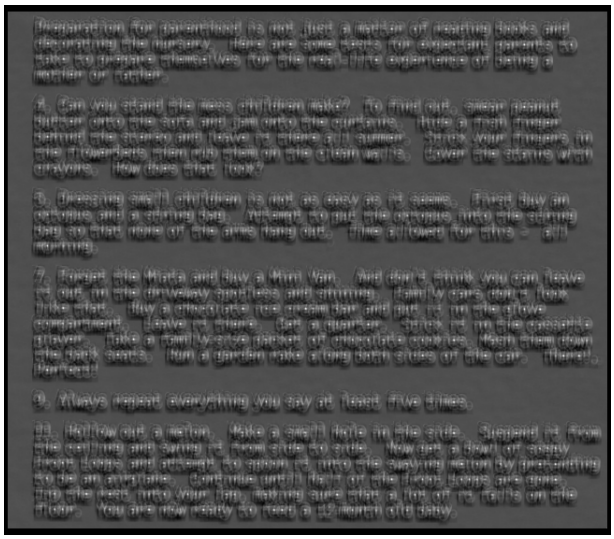

Figure 2: MSF Image

Here, we can see that the input image is blurred and at positions where the image has the letter 'e' or a letter that closely resembles the letter 'e', a bright white spot is seen. Indicating that these locations have a high response to the input template.

2.2 Tresholding

Using a provided Ground Truth file, we iterate through each Ground Truth letter position and check if at that position we detect any letter. This 'detection' is manifested by thresholding the MSF image at a particular threshold. We classify each of the regions above this threshold as a detection of the letter 'e' and a absence of the letter when the MSF value is below the threshold. If that detected letter is a 'e' then we count it towards True Positives, if the Ground Truth label is different from an 'e', then we count it towards False Positives.

Listing 2: Thresholding the MSF Image

```
   /* gt_yes and gt_no for True and False Positive rates */
gt_yes=0;gt_no=0;
for(i=0; i<TOTAL_DATA; i++)
  if(gt_c[i]=='e')
     gt_yes++;
  else
     gt_no++;


       /* checking the image, skipping the border points */
tp=0;fp=0;
for (i=0; i<TOTAL_DATA; i++) //Iterating over data in Ground Truth file
 for (r2=-7; r2<7; r2++)
   for (c2=-4; c2<4; c2++)
     {
       r=gt_y[i]; c=gt_x[i];
       if(image[(r+r2)*COLS_i+(c+c2)]>Tresh)
```

```
    {
     r2=7;c2=4; //check for at least one occurrence
     if(gt_c[i]=='e')
       tp++;
     else
       fp++;
    }
  }
```

The C implementation of the above description is given above.

Once we have a count of True Positives and False Positives for each threshold value, we plot an 'ROC' curve to find the optimum threshold value. This value ideally should be one where the True Positive value is at its highest and the False Positive value is at its lowest. This is generally depicted in the ROC curve as a 'knee' point.

Here is the ROC curve generated for Threshold values from 0-255

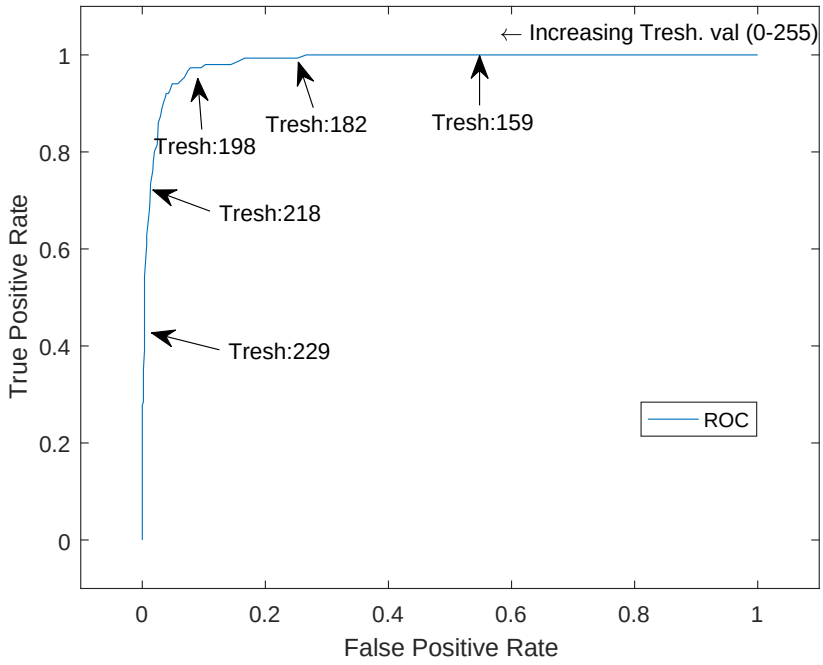

Figure 3: ROC Curve for Threshold range 0-255

Here we see that initially both TPR (True Positive rate) and FPR (False Positive Rate) start at 1 and then tend to decrease towards zero. The FPR decreases faster than the TPR, a point where TPR is as high as possible and FPR is as low as possible would be an ideal choice for an optimal threshold.

3 Results

To chose the right threshold value, we ideally chose a point with a low enough False Positive Rate and a high enough True Positive Rate. This is generally found near the 'Knee'.

Here is a comparison of the True Positives and False Positives around the 'Knee'.

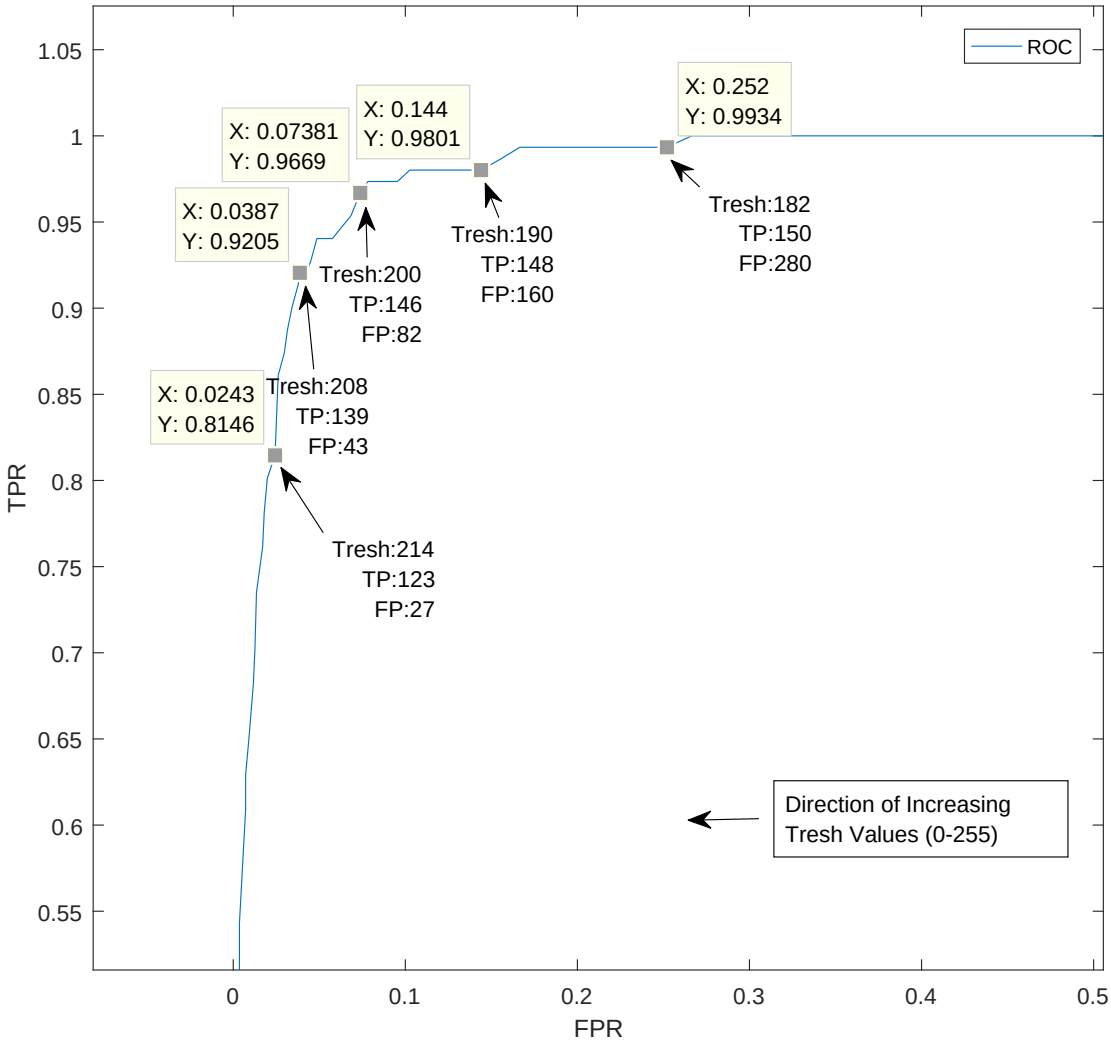

Figure 4: TP and FP values near the 'Knee'

From this result, choosing a Threshold of **208** seems appropriate. It has a high enough TPR of 92% (TP:139) and a low enough FPR of 3.8% (FP:43). Thresholds above 208 have a lower TPR value, and thresholds below have a higher FPR value.