CSC 249 Homework 4 Report

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1 Introduction

For this homework assignment, we were tasked with using the Hough Transform to identify lines in an image. The Hough Transform uses a consensus-based approach to pattern identification, testing many possible line positions and then adding all of the possibilities together to determine the most prominent lines. I implemented the transform and applied it to the image from Homework 2. I successfully completed all stages of the assignment, as well as plotting the resulting identified lines on the original image.

2 How to Run

2.1 Dependencies

Some of my code may require the Image Processing Toolkit to run. If it is not installed, MATLAB will show an error indicating so.

2.2 Running the program

To start the program, please run `Homework04.m`. The program will load the image that was provided for this project from the `Input` folder, and output images representing all stages of the process into the `Output` folder. The files outputted are as follows:

- `1_highpass`: The output of the high-pass algorithm (Edge image).
- `2_hough`: The output of the Hough Transform.
- `3_median`: The output of the Hough Transform, with a median filter applied.
- `4_lines`: The output of the Hough Transform, with circles overlaid on the positions that have been chosen as maxima and will have their lines graphed.
- `5_extra`: The original image, with lines overlaid.

These images are also displayed in this document.

3 Procedure

3.1 Edge Detection

The Hough Transform requires the image to be given in the form of an edge image. The reason for this is because if the algorithm was given an image with solid shapes, it would identify many false lines within the solid body of the object.

To generate the edge image from the original input image, I applied a high-pass filter to the image, using the following filter kernel:

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

3.2 Hough Transform

The first step of the Hough Transform is to create an empty "consensus" image which will store the overlapping values from the transform algorithm. This image, also called the parameter space image, will be a 2d representation of a polar coordinate system. The Y axis represents the distance from center, and the X axis represents the angle of the line.

Next, the algorithm loops through each X and Y position in the original image, and if an edge pixel exists in this location, plot a curve on the consensus image corresponding to lines of varying angles that pass through this point.

Individually, these steps are simple, but they overlap on the consensus image, and the pixels on the consensus image with the highest values indicate a line at that set of polar coordinates.

3.3 Line Plotting

The Hough Transform returns a graph that can then be used to identify the lines in the original image by analyzing the positions of the maxima in the transform image.

To identify the maxima in the graph, I manually selected and built a list of the points in the image I believed to be maxima. I did this because manual selection worked better than having an algorithm pick the items. An algorithm would be susceptible to inaccuracies due to floating point math and pixel rounding, which would have altered the result and incorrectly placed some lines. By manually recording the maxima in the image, I avoided this issue.

In future projects, I would eliminate this problem by generating the Hough Transform at a higher resolution to eliminate the inaccuracies due to saving the graph as a pixel image.

After obtaining the list of maxima, I used MATLAB to plot these on the parameter space graph and plot the lines on the original image to verify that the algorithm correctly identified the lines.

4 Results and Analysis

4.1 Edge Detection

The original image and the resulting edge image from the high-pass filter are shown below.

Figure 1: Original Image

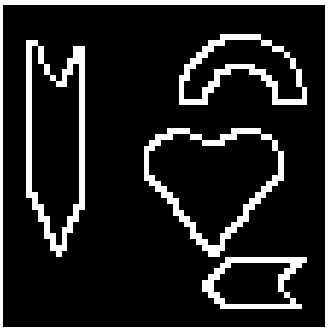

Figure 2: Edge Image

4.2 Hough Transform

The parameter space output from the Hough Transform algorithm is shown below. As described in the Procedure section, the image is made up of many line plots that overlap to determine the most likely positions in the original image for a line. The areas with bright color are maxima and will be marked as lines.

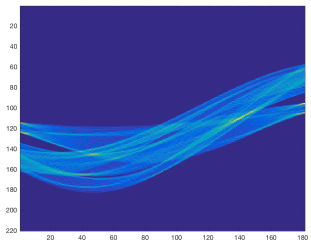

Figure 3: Hough Transform

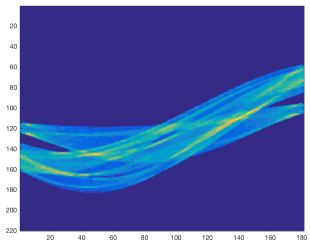

Figure 4: Hough Transform (Median)

To aid in analysis and placement of maxima points, I applied a median filter to the Hough Transform image, seen on the right. This eliminates some of the smaller maxima that are insignificant. The result of determining the maxima of the image is shown on the Hough Transform image below, with maxima seen as circles.

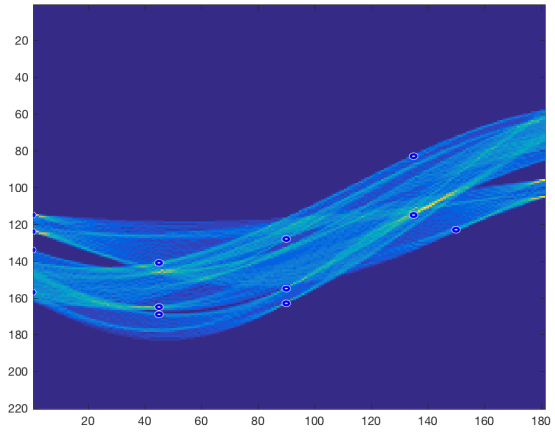

Figure 5: Hough Transform, With Chosen Maxima

I noticed that the brighter the line, the longer the original line is in the image. This is because the longer lines have more pixels in them, and since each pixel adds to the consensus image, the lines with many pixels will be very bright.

The polar representation has several traits that make it work better than a linear (Cartesian) representation.

A Cartesian line is usually defined in terms of a slope, for example, in slope-intercept form. This means that the Cartesian representation is very bad at representing vertical lines. For a perfectly vertical line, the slope must approach Infinity, and shifting a vertical line horizontally will require constant values that also approach Infinity. Because of this, the Cartesian representation requires separate accumulators for mostly-horizontal and mostly-vertical lines, and is a bad solution for a computer-based system which works well with discrete sizes and small numbers. In contrast, the Polar coordinate system can represent any line while keeping values within a defined bounds, which works well for a computer algorithm because we only need a single accumulator of a defined size.

4.3 Line Plotting

Once I chose the maxima in the parameter space image, I used an algorithm that converted the maxima coordinates back into a line equation which could then be plotted on top of the original image. The result of this process is seen below.

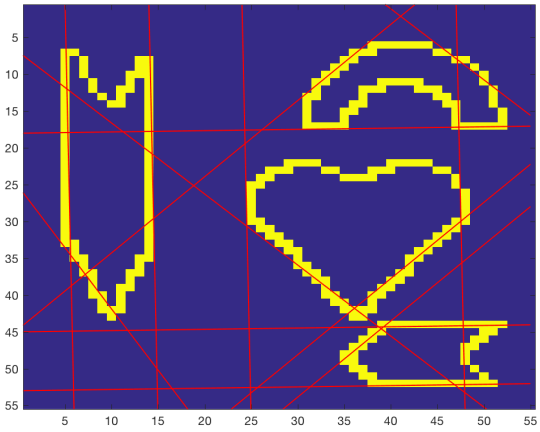

Figure 6: Original Image, Lines Highlighted

As you can see, the Hough Transform has successfully identified the major lines in the image. Some of the lines are not highlighted in the image; this is because my choice of which maxima to plot left out some of the less major lines for the sake of clearly showing the major lines. By choosing a different threshold value, one can show or hide more of the detected lines.

4.4 Extra Credit

For extra credit on this project, I chose to plot the maxima on the original image so that the result of the Hough transform could more clearly be seen. This was shown above in the Results section.

5 Academic Honesty

I did not collaborate on this assignment and all work is my own.