Hough Line Transform

Prev Tutorial: Canny Edge Detector

Next Tutorial: Hough Circle Transform

Goal

In this tutorial you will learn how to:

- Use the OpenCV functions **HoughLines()** and **HoughLinesP()** to detect lines in an image.

Theory

Note
The explanation below belongs to the book **Learning OpenCV** by Bradski and Kaehler.

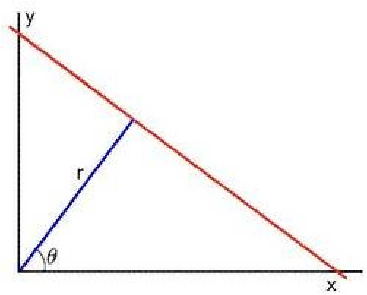
Hough Line Transform

1. The Hough Line Transform is a transform used to detect straight lines.
2. To apply the Transform, first an edge detection pre-processing is desirable.

How does it work?

1. As you know, a line in the image space can be expressed with two variables. For example:

    a. In the **Cartesian coordinate system:** Parameters: (m, b).
    b. In the **Polar coordinate system:** Parameters: (r, θ)



For Hough Transforms, we will express lines in the *Polar system*. Hence, a line equation can be written as:

$$y = \left(-\frac{\cos\theta}{\sin\theta}\right)x + \left(\frac{r}{\sin\theta}\right)$$

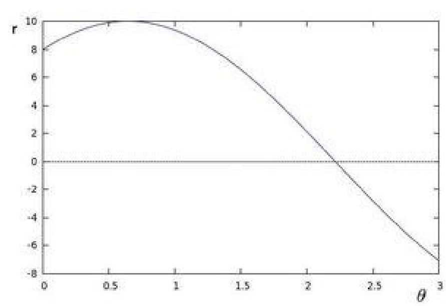
Arranging the terms: $r = x\cos\theta + y\sin\theta$

1. In general for each point (x_0, y_0), we can define the family of lines that goes through that point as:

$$r_\theta = x_0 \cdot \cos\theta + y_0 \cdot \sin\theta$$

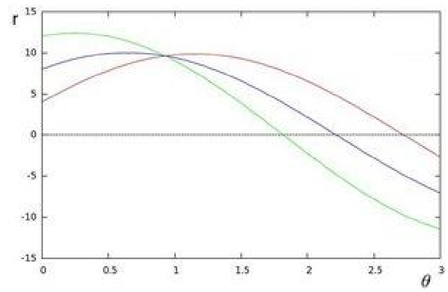
Meaning that each pair (r_θ, θ) represents each line that passes by (x_0, y_0).

2. If for a given (x_0, y_0) we plot the family of lines that goes through it, we get a sinusoid. For instance, for $x_0 = 8$ and $y_0 = 6$ we get the following plot (in a plane θ - r):



We consider only points such that $r > 0$ and $0 < \theta < 2\pi$.

3. We can do the same operation above for all the points in an image. If the curves of two different points intersect in the plane θ - r, that means that both points belong to a same line. For instance, following with the example above and drawing the plot for two more points: $x_1 = 4$, $y_1 = 9$ and $x_2 = 12$, $y_2 = 3$, we get:

   The three plots intersect in one single point $(0.925, 9.6)$, these coordinates are the parameters (θ, r) or the line in which (x_0, y_0), (x_1, y_1) and (x_2, y_2) lay.

4. What does all the stuff above mean? It means that in general, a line can be *detected* by finding the number of intersections between curves.The more curves intersecting means that the line represented by that intersection have more points. In general, we can define a *threshold* of the minimum number of intersections needed to *detect* a line.
5. This is what the Hough Line Transform does. It keeps track of the intersection between curves of every point in the image. If the number of intersections is above some *threshold*, then it declares it as a line with the parameters (θ, r_θ) of the intersection point.

Standard and Probabilistic Hough Line Transform

OpenCV implements two kind of Hough Line Transforms:

a. **The Standard Hough Transform**

- It consists in pretty much what we just explained in the previous section. It gives you as result a vector of couples (θ, r_θ)
- In OpenCV it is implemented with the function **HoughLines()**

b. **The Probabilistic Hough Line Transform**

- A more efficient implementation of the Hough Line Transform. It gives as output the extremes of the detected lines (x_0, y_0, x_1, y_1)
- In OpenCV it is implemented with the function **HoughLinesP()**

What does this program do?

- Loads an image
- Applies a *Standard Hough Line Transform* and a *Probabilistic Line Transform*.
- Display the original image and the detected line in three windows.

Code

C++ Java Python

The sample code that we will explain can be downloaded from here.

```
"""
@file hough_lines.py
@brief This program demonstrates line finding with the Hough transform
"""
import sys
import math
import cv2 as cv
import numpy as np


def main(argv):

    default_file = 'sudoku.png'
    filename = argv[0] if len(argv) > 0 else default_file

    # Loads an image
    src = cv.imread(cv.samples.findFile(filename), cv.IMREAD_GRAYSCALE)

    # Check if image is loaded fine
    if src is None:
        print ('Error opening image!')
        print ('Usage: hough_lines.py [image_name -- default ' + default_file + '] \n')
        return -1


    dst = cv.Canny(src, 50, 200, None, 3)
```

```
    # Copy edges to the images that will display the results in BGR
    cdst = cv.cvtColor(dst, cv.COLOR_GRAY2BGR)
    cdstP = np.copy(cdst)


    lines = cv.HoughLines(dst, 1, np.pi / 180, 150, None, 0, 0)

    if lines is not None:
        for i in range(0, len(lines)):
            rho = lines[i][0][0]
            theta = lines[i][0][1]
            a = math.cos(theta)
            b = math.sin(theta)
            x0 = a * rho
            y0 = b * rho
            pt1 = (int(x0 + 1000*(-b)), int(y0 + 1000*(a)))
            pt2 = (int(x0 - 1000*(-b)), int(y0 - 1000*(a)))

            cv.line(cdst, pt1, pt2, (0,0,255), 3, cv.LINE_AA)



    linesP = cv.HoughLinesP(dst, 1, np.pi / 180, 50, None, 50, 10)

    if linesP is not None:
        for i in range(0, len(linesP)):
            l = linesP[i][0]
            cv.line(cdstP, (l[0], l[1]), (l[2], l[3]), (0,0,255), 3, cv.LINE_AA)

    cv.imshow("Source", src)
    cv.imshow("Detected Lines (in red) - Standard Hough Line Transform", cdst)
    cv.imshow("Detected Lines (in red) - Probabilistic Line Transform", cdstP)

    cv.waitKey()
    return 0


if __name__ == "__main__":
    main(sys.argv[1:])
```

Explanation

C++ Java Python

Load an image:

```
    default_file = 'sudoku.png'
    filename = argv[0] if len(argv) > 0 else default_file

    # Loads an image
    src = cv.imread(cv.samples.findFile(filename), cv.IMREAD_GRAYSCALE)

    # Check if image is loaded fine
    if src is None:
        print ('Error opening image!')
        print ('Usage: hough_lines.py [image_name -- default ' + default_file + '] \n')
        return -1
```

Detect the edges of the image by using a Canny detector:

```
    # Edge detection
    dst = cv.Canny(src, 50, 200, None, 3)
```

Now we will apply the Hough Line Transform. We will explain how to use both OpenCV functions available for this purpose.

Standard Hough Line Transform:

First, you apply the Transform:

```
    #  Standard Hough Line Transform
    lines = cv.HoughLines(dst, 1, np.pi / 180, 150, None, 0, 0)
```

- with the following arguments:
  - *dst*: Output of the edge detector. It should be a grayscale image (although in fact it is a binary one)
  - *lines*: A vector that will store the parameters (r, θ) of the detected lines
  - *rho* : The resolution of the parameter r in pixels. We use **1** pixel.
  - *theta*: The resolution of the parameter θ in radians. We use **1 degree** (CV_PI/180)
  - *threshold*: The minimum number of intersections to "*detect*" a line
  - *srn* and *stn*: Default parameters to zero. Check OpenCV reference for more info.

And then you display the result by drawing the lines.

```
    # Draw the lines
    if lines is not None:
        for i in range(0, len(lines)):
            rho = lines[i][0][0]
```

```
            theta = lines[i][0][1]
            a = math.cos(theta)
            b = math.sin(theta)
            x0 = a * rho
            y0 = b * rho
            pt1 = (int(x0 + 1000*(-b)), int(y0 + 1000*(a)))
            pt2 = (int(x0 - 1000*(-b)), int(y0 - 1000*(a)))

            cv.line(cdst, pt1, pt2, (0,0,255), 3, cv.LINE_AA)
```

Probabilistic Hough Line Transform

First you apply the transform:

```
    # Probabilistic Line Transform
    linesP = cv.HoughLinesP(dst, 1, np.pi / 180, 50, None, 50, 10)
```

- with the arguments:
  - *dst*: Output of the edge detector. It should be a grayscale image (although in fact it is a binary one)
  - *lines*: A vector that will store the parameters $(x_{start}, y_{start}, x_{end}, y_{end})$ of the detected lines
  - *rho* : The resolution of the parameter r in pixels. We use **1** pixel.
  - *theta*: The resolution of the parameter θ in radians. We use **1 degree** (CV_PI/180)
  - *threshold*: The minimum number of intersections to "*detect*" a line
  - *minLinLength*: The minimum number of points that can form a line. Lines with less than this number of points are disregarded.
  - *maxLineGap*: The maximum gap between two points to be considered in the same line.

And then you display the result by drawing the lines.

```
    # Draw the lines
    if linesP is not None:
        for i in range(0, len(linesP)):
            l = linesP[i][0]
            cv.line(cdstP, (l[0], l[1]), (l[2], l[3]), (0,0,255), 3, cv.LINE_AA)
```

Display the original image and the detected lines:

```
    # Show results
    cv.imshow("Source", src)
    cv.imshow("Detected Lines (in red) - Standard Hough Line Transform", cdst)
    cv.imshow("Detected Lines (in red) - Probabilistic Line Transform", cdstP)
```

Wait until the user exits the program

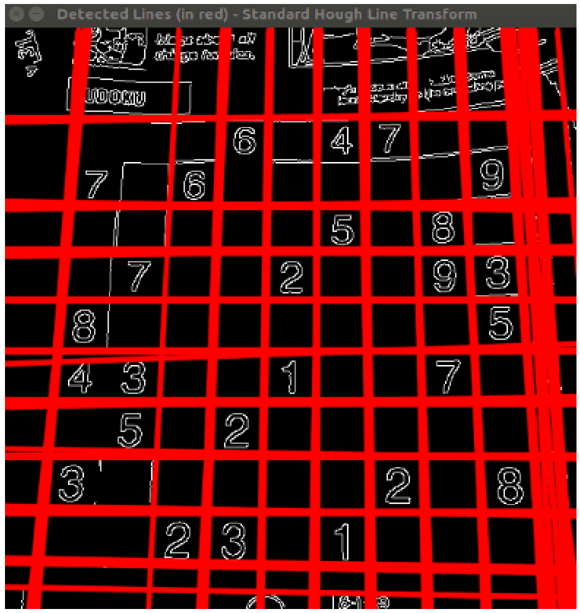
```
    # Wait and Exit
    cv.waitKey()
    return 0
```

Result

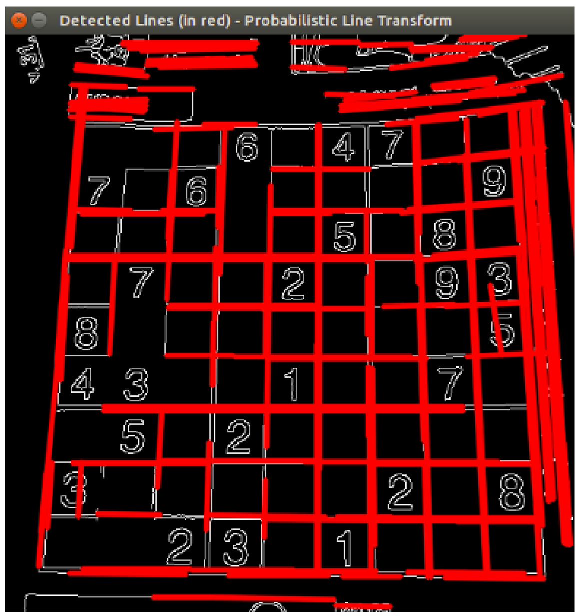
Note

The results below are obtained using the slightly fancier version we mentioned in the *Code* section. It still implements the same stuff as above, only adding the Trackbar for the Threshold.

Using an input image such as a sudoku image. We get the following result by using the Standard Hough Line Transform:



And by using the Probabilistic Hough Line Transform:



You may observe that the number of lines detected vary while you change the *threshold*. The explanation is sort of evident: If you establish a higher threshold, fewer lines will be detected (since you will need more points to declare a line detected).