Hough Line Transform¶

docs.opencv.org/2.4/doc/tutorials/imgproc/imgtrans/hough_lines/hough_lines.html

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.

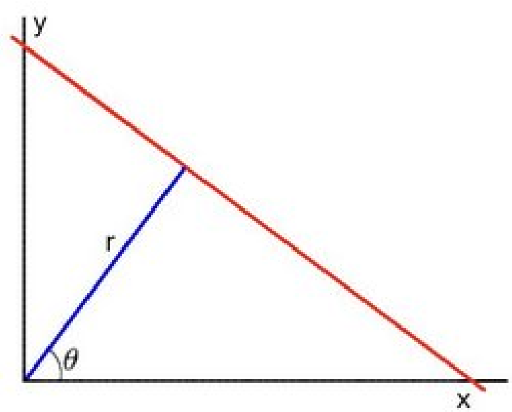
1. The Hough Line Transform is a transform used to detect straight lines.
2. To apply the Transform, first an edge detection pre-processing is desirable.

How does it work?¶

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

    1. In the **Cartesian coordinate system:** Parameters: (m, b).
    2. 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:

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

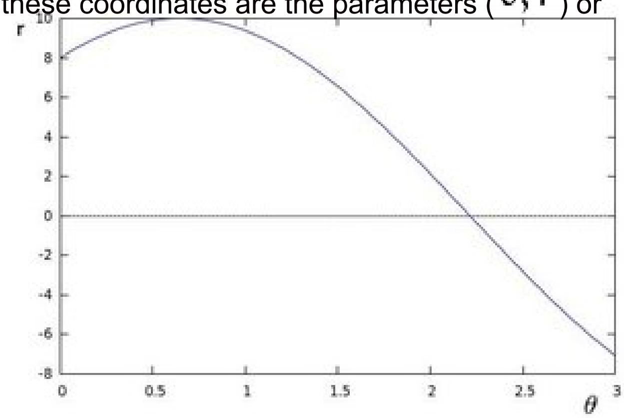
    Meaning that each pair (r_θ, θ) represents each line that passes by (x_0, y_0).

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 $0 < \theta < 2\pi$.

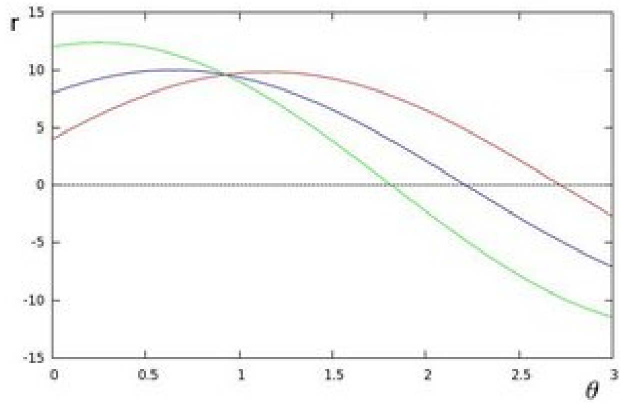
3. We can do the same operation above for all the points in an image. If the curves of two different points intersect in the plane θ - r, that means that both points belong to a same line. For instance, following with the example above and drawing the plot for two more points: $x_1 = 4$, $y_1 = 9$ and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

1. **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*]

2. **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*]

Code¶

1. **What does this program do?**
   - Loads an image
   - Applies either a *Standard Hough Line Transform* or a *Probabilistic Line Transform*.
   - Display the original image and the detected line in two windows.

2. The sample code that we will explain can be downloaded from here. A slightly fancier version (which shows both Hough standard and probabilistic with trackbars for changing the threshold values) can be found here.

```
#include "opencv2/highgui/highgui.hpp"
#include "opencv2/imgproc/imgproc.hpp"

#include <iostream>

using namespace cv;
using namespace std;

void help()
{
 cout << "\nThis program demonstrates line finding with the Hough transform.\n"
         "Usage:\n"
         "./houghlines <image_name>, Default is pic1.jpg\n" << endl;
}

int main(int argc, char** argv)
{
 const char* filename = argc >= 2 ? argv[1] : "pic1.jpg";

 Mat src = imread(filename, 0);
 if(src.empty())
 {
     help();
     cout << "can not open " << filename << endl;
     return -1;
 }

 Mat dst, cdst;
 Canny(src, dst, 50, 200, 3);
 cvtColor(dst, cdst, CV_GRAY2BGR);

 #if 0
  vector<Vec2f> lines;
  HoughLines(dst, lines, 1, CV_PI/180, 100, 0, 0 );

  for( size_t i = 0; i < lines.size(); i++ )
  {
     float rho = lines[i][0], theta = lines[i][1];
     Point pt1, pt2;
     double a = cos(theta), b = sin(theta);
     double x0 = a*rho, y0 = b*rho;
     pt1.x = cvRound(x0 + 1000*(-b));
     pt1.y = cvRound(y0 + 1000*(a));
     pt2.x = cvRound(x0 - 1000*(-b));
     pt2.y = cvRound(y0 - 1000*(a));
     line( cdst, pt1, pt2, Scalar(0,0,255), 3, CV_AA);
  }
 #else
  vector<Vec4i> lines;
  HoughLinesP(dst, lines, 1, CV_PI/180, 50, 50, 10 );
  for( size_t i = 0; i < lines.size(); i++ )
  {
    Vec4i l = lines[i];
    line( cdst, Point(l[0], l[1]), Point(l[2], l[3]), Scalar(0,0,255), 3,
CV_AA);
  }
```

```
 #endif
 imshow("source", src);
 imshow("detected lines", cdst);

 waitKey();

 return 0;
}
```

Explanation¶

1. Load an image

   ```
   Mat src = imread(filename, 0);
   if(src.empty())
   {
     help();
     cout << "can not open " << filename <<
   endl;
     return -1;
   }
   ```

2. Detect the edges of the image by using a Canny detector

   ```
   Canny(src, dst, 50, 200, 3);
   ```

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

3. **Standard Hough Line Transform**

   1. First, you apply the Transform:

      ```
      vector<Vec2f> lines;
      HoughLines(dst, lines, 1, CV_PI/180, 100, 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.

   2. And then you display the result by drawing the lines.

```
for( size_t i = 0; i < lines.size(); i++ )
{
  float rho = lines[i][0], theta = lines[i][1];
  Point pt1, pt2;
  double a = cos(theta), b = sin(theta);
  double x0 = a*rho, y0 = b*rho;
  pt1.x = cvRound(x0 + 1000*(-b));
  pt1.y = cvRound(y0 + 1000*(a));
  pt2.x = cvRound(x0 - 1000*(-b));
  pt2.y = cvRound(y0 - 1000*(a));
  line( cdst, pt1, pt2, Scalar(0,0,255), 3, CV_AA);
}
```

4. **Probabilistic Hough Line Transform**

    1. First you apply the transform:

    ```
    vector<Vec4i> lines;
    HoughLinesP(dst, lines, 1, CV_PI/180, 50, 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.

    2. And then you display the result by drawing the lines.

    ```
    for( size_t i = 0; i < lines.size(); i++ )
    {
      Vec4i l = lines[i];
      line( cdst, Point(l[0], l[1]), Point(l[2], l[3]), Scalar(0,0,255), 3,
    CV_AA);
    }
    ```

5. Display the original image and the detected lines:

```
imshow("source", src);
imshow("detected lines",
cdst);
```

6. Wait until the user exits the program

```
waitKey();
```

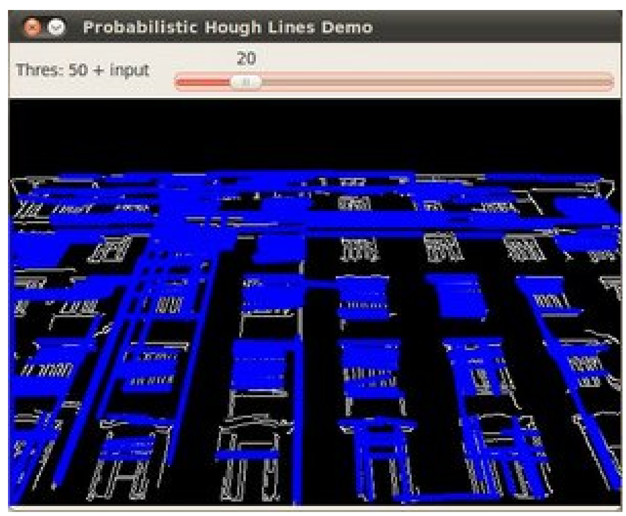
Result¶

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:

We get the following result 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).