Hough Transform with OpenCV (C++/Python)

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In this post, we will learn how to detect lines and circles in an image, with the help of a technique called Hough transform.

What is Hough transform?

Hough transform is a feature extraction method for detecting simple shapes such as circles, lines etc in an image.

A “simple” shape is one that can be represented by only a few parameters. For example, a line can be represented by two parameters (slope, intercept) and a circle has three parameters — the coordinates of the center and the radius (x, y, r). Hough transform does an excellent job in finding such shapes in an image.

The main advantage of using the Hough transform is that it is insensitive to occlusion.

Let’s see how Hough transform works by way of an example.

Hough transform to detect lines in an image

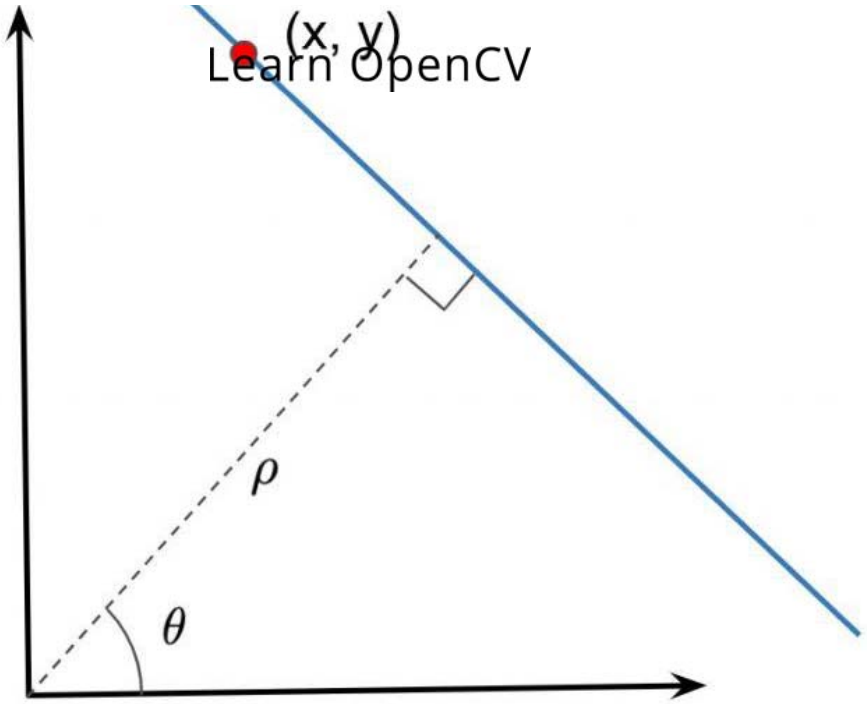


Fig.1 : A line in polar coordinates

Equation of a line in polar coordinates

From high school math class we know the polar form of a line is represented as:

$$\rho = x\cos(\theta) + y\sin(\theta) \tag{1}$$

Here ρ represents the perpendicular distance of the line from the origin in pixels, and θ is the angle measured in radians, which the line makes with the origin as shown in the figure above.

You may be tempted to ask why we did not use the familiar equation of the line given below

$$y = mx + c$$

The reason is that the slope, m, can take values between $-\infty$ to $+\infty$. For the Hough transform, the parameters need to be bounded.

You may also have a follow-up question. In the (ρ, θ) form, θ is bounded, but can't ρ take a value between 0 to $+\infty$? That may be true in theory, but in practice, ρ is also bounded because the image itself is finite.

Accumulator

When we say that a line in 2D space is parameterized by ρ and θ, it means that if we any pick a (ρ, θ), it corresponds to a line.

Imagine a 2D array where the x-axis has all possible θ values and the y-axis has all possible ρ values. Any bin in this 2D array corresponds to one line.

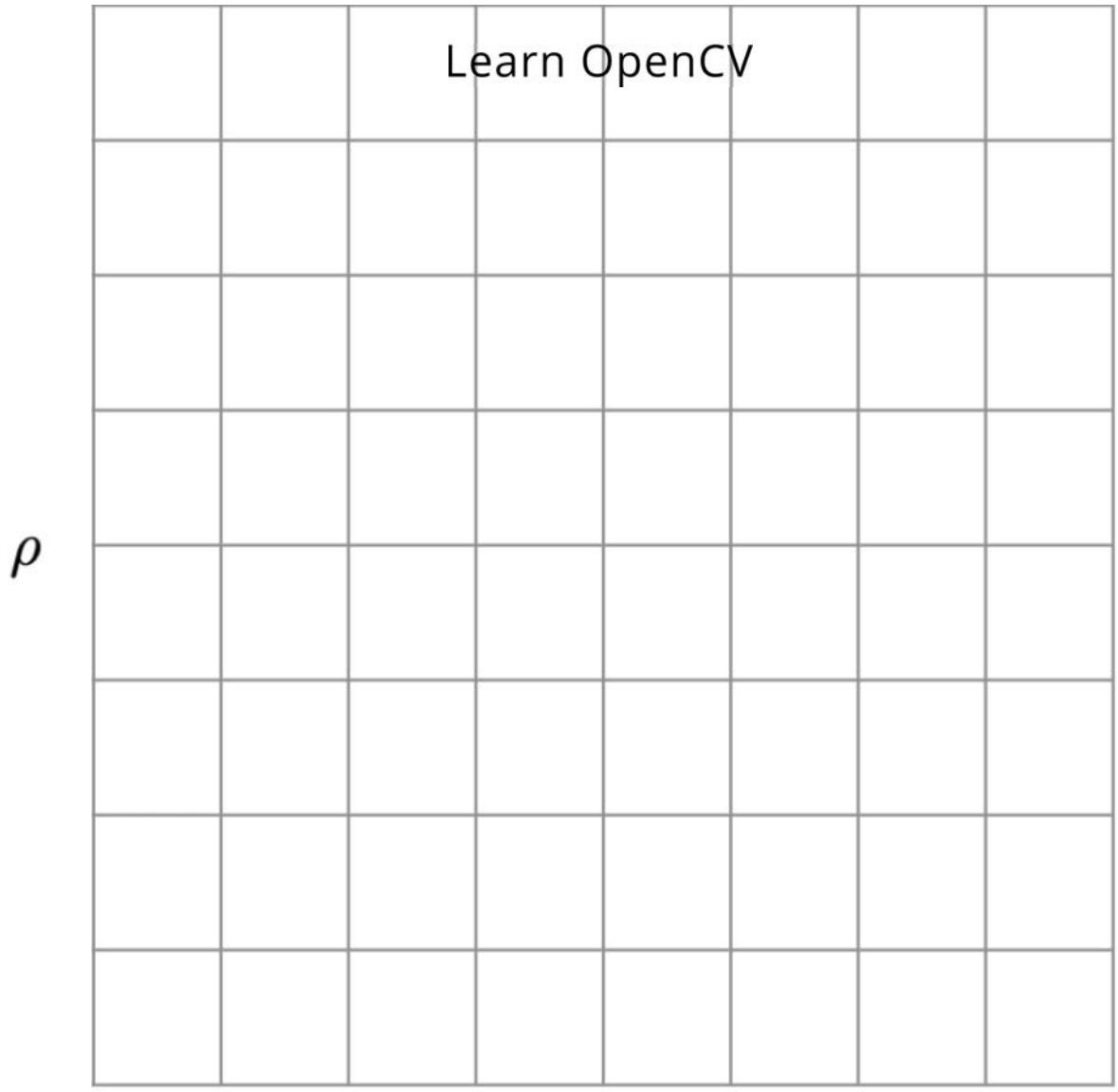


Fig.2 : Accumulator

This 2D array is called an **accumulator** because we will use the bins of this array to collect evidence about which lines exist in the image. The top left cell corresponds to a (-R, 0) and the bottom right corresponds to (R, π).

We will see in a moment that the value inside the bin (ρ, θ) will increase as more evidence is gathered about the presence of a line with parameters ρ and θ.

The following steps are performed to detect lines in an image.

Step 1 : Initialize Accumulator

First, we need to create an accumulator array. The number of cells you choose to have is a design decision. Let's say you chose a 10×10 accumulator. It means that ρ can take only 10 distinct values and the θ can take 10 distinct values, and therefore you will be able to detect 100 different kinds of lines. The size of the accumulator will also depend on the resolution of the image. But if you are just starting, don't worry about getting it perfectly right. Pick a number like 20×20 and see what results you get.

Step 2: Detect Edges

Now that we have set up the accumulator, we want to collect evidence for every cell of the accumulator because every cell of the accumulator corresponds to one line.

How do we collect evidence?

The idea is that if there is a visible line in the image, an edge detector should fire at the boundaries of the line. These edge pixels provide evidence for the presence of a line.

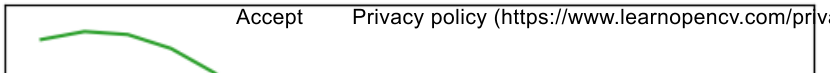
The output of edge detection is an array of edge pixels $[(x_1, y_1), (x_2, y_2)...(x_n, y_n)]$

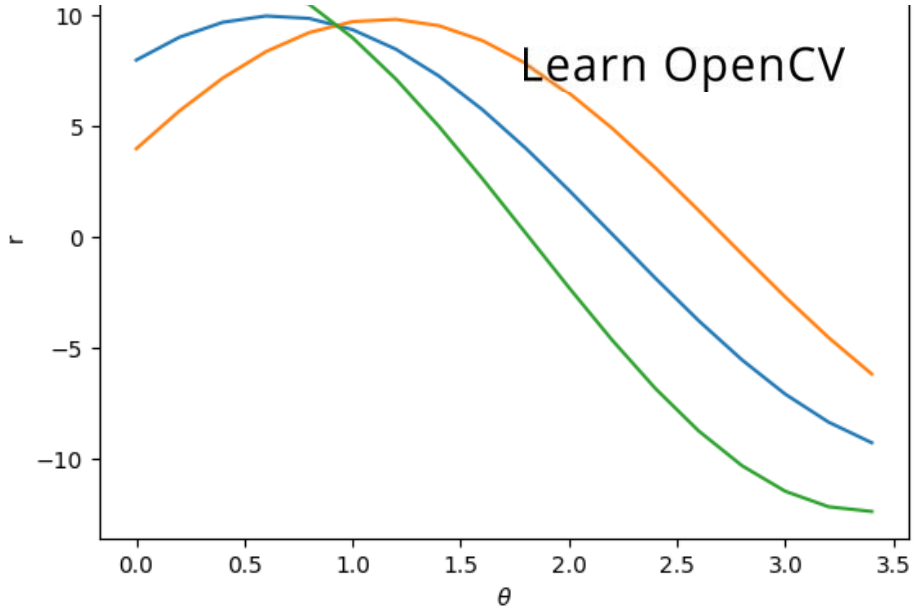
Step 3: Voting by Edge Pixels

For every edge pixel (x, y) in the above array, we vary the values of θ from 0 to π and plug it in equation 1 to obtain a value for ρ.

In the Figure below we vary the θ for three pixels (represented by the three colored curves), and obtain the values for ρ using equation 1.

As you can see, these curves intersect at a point indicating that a line with parameters $\theta = 1$ and $\rho = 9.5$ is passing through them.





Typically, we have hundreds of edge pixels and the accumulator is used to find the intersection of all the curves generated by the edge pixels.

Let's see how this is done.

Let's say our accumulator is 20×20 in size. So, there are 20 distinct values of θ and so for every edge pixel (x, y), we can calculate 20 (ρ, θ) pairs by using equation 1. The bin of the accumulator corresponding to these 20 values of (ρ, θ) is incremented.

We do this for every edge pixel and now we have an accumulator that has all the evidence about all possible lines in the image.

We can simply select the bins in the accumulator above a certain threshold to find the lines in the image. If the threshold is higher, you will find fewer strong lines, and if it is lower, you will find a large number of lines including some weak ones.

HoughLine: How to Detect Lines using OpenCV

Download Code To easily follow along this tutorial, please download code by clicking on the button below. It's FREE!

In OpenCV, line detection using Hough Transform is implemented in the function **HoughLines** and **HoughLinesP** [Probabilistic Hough Transform]. This function takes the following arguments:

- *edges*: Output of the edge detector.
- *lines*: A vector to store the coordinates of the start and end of the line.
- *rho:* The resolution parameter ρ in pixels.
- *theta*: The resolution of the parameter θ in radians.
- *threshold*: The minimum number of intersecting points to detect a line.

Python:

```python
# Read image
img = cv2.imread('lanes.jpg', cv2.IMREAD_COLOR) # road.png is the filename
# Convert the image to gray-scale
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
# Find the edges in the image using canny detector
edges = cv2.Canny(gray, 50, 200)
# Detect points that form a line
lines = cv2.HoughLinesP(edges, 1, np.pi/180, max_slider, minLineLength=10, maxLineGap=250)
# Draw lines on the image
for line in lines:
    x1, y1, x2, y2 = line[0]
    cv2.line(img, (x1, y1), (x2, y2), (255, 0, 0), 3)
# Show result
cv2.imshow("Result Image", img)
```

C++:

```cpp
// Read the image as gray-scale
Mat img = imread('lanes.jpg', IMREAD_COLOR);
// Convert to gray-scale
Mat gray = cvtColor(img, COLOR_BGR2GRAY);
// Store the edges
Mat edges;
// Find the edges in the image using canny detector
```

```
Canny(gray, edges, 50, 200);
// Create a vector to store lines of the image
vector<Vec4i> lines;
// Apply Hough Transform
HoughLinesP(edges, lines, 1, CV_PI/180, thresh, 10, 250);
// Draw lines on the image
for (size_t i=0; i<lines.size(); i++) {
    Vec4i l = lines[i];
    line(src, Point(l[0], l[1]), Point(l[2], l[3]), Scalar(255, 0, 0), 3, LINE_AA);
}
// Show result image
imshow("Result Image", img);
```


Line Detection Result

Below we show a result of using hough transform for line detection. Bear in mind the quality of detected lines depends heavily on the quality of the edge map. Therefore, in the real world Hough transform is used when you can control the environment and therefore obtain consistent edge maps or when you can train an edge detector for the specific kind of edges you are looking for.

Line Detection using Hough Transform

HoughCircles : Detect circles in an image with OpenCV

In the case of line Hough transform, we required two parameters, (θ, ρ) but to detect circles, we require three parameters

- coordinates of the center of the circle.
- radius.

As you can imagine, a circle detector will require a 3D accumulator — one for each parameter.

The equation of a circle is given by

(2)

The following steps are followed to detect circles in an image: –

1. Find the edges in the given image with the help of edge detectors (Canny).
2. For detecting circles in an image, we set a threshold for the maximum and minimum value of the radius.
3. Evidence is collected in a 3D accumulator array for the presence of circles with different centers and radii.

The function **HoughCircles** is used in OpenCV to detect the circles in an image. It takes the following parameters:

- *image*: The input image.
- *method*: Detection method.
- *dp*: the Inverse ratio of accumulator resolution and image resolution.
- *mindst*: minimum distance between centers od detected circles.
- *param_1* and *param_2*: These are method specific parameters.
- *min_Radius*: minimum radius of the circle to be detected.
- *max_Radius:* maximum radius to be detected.

Python:

```
# Read image as gray-scale
img = cv2.imread('circles.png', cv2.IMREAD_COLOR)
# Convert to gray-scale
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
# Blur the image to reduce noise
img_blur = cv2.medianBlur(gray, 5)
# Apply hough transform on the image
circles = cv2.HoughCircles(img_blur, cv2.HOUGH_GRADIENT, 1, img.shape[0]/64, param1=200, param2=10,
minRadius=5, maxRadius=30)
# Draw detected circles

if circles is not None:
    circles = np.uint16(np.around(circles))
    for i in circles[0, :]:
        # Draw outer circle
        cv2.circle(img, (i[0], i[1]), i[2], (0, 255, 0), 2)
        # Draw inner circle
```

```
        cv2.circle(img, (i[0], i[1]), 2, (0, 0, 255), 3)
```


C++:

```
// Read the image as gray-scale
img = imread("circles.png", IMREAD_COLOR);
// Convert to gray-scale
gray = cvtColor(img, COLOR_BGR2GRAY);
// Blur the image to reduce noise
Mat img_blur;
medianBlur(gray, img_blur, 5);
// Create a vector for detected circles
vector<Vec3f>  circles;
// Apply Hough Transform
HoughCircles(img_blur, circles, HOUGH_GRADIENT, 1, img.rows/64, 200, 10, 5, 30);
// Draw detected circles
for(size_t i=0; i<circles.size(); i++) {
    Point center(cvRound(circles[i][0]), cvRound(circles[i][1]));
    int radius = cvRound(circles[i][2]);
    circle(img, center, radius, Scalar(255, 255, 255), 2, 8, 0);
}
```

HoughCircles function has inbuilt canny detection, therefore it is not required to detect edges explicitly in it.

Circle Detection Result

The result of circle detection using Hough transform is shown below. The quality of result depends heavily on the quality of edges you can find, and also on how much prior knowledge you have about the size of the circle you want to detect.

Circle Detection using Hough Transform

Circle detection using Hough transform with OpenCV

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Stephen Meschke • a year ago
I started with an image that contained a diagonal line of dots.

Using this Python script, I calculated the accumulator array and found the brightest spot.

How do I get from the bright spot in the accumulator image to the $y = mx + b$ equation for the line?

4 ^ | v • Reply • Share ›

Daniel Friedman ➚ Stephen Meschke • a year ago

Find the indices of the max in accumulator array, convert these to rho and theta values, and finally plug into the polar form to get an equation in terms of x and y.

^ | v • Reply • Share ›

Piero Toffanin • a year ago

Excellent read! Thank you!!

4 ^ | v • Reply • Share ›

Satya Mallick Mod ➚ Piero Toffanin • a year ago

Thanks!

5 ^ | v • Reply • Share ›

_min • 7 months ago

max_slider is not defined in your Python code example.

1 ^ | v • Reply • Share ›

Alessandro N ➚ _min • 5 months ago

True !

I want to remover horizontal lines from image attachment

^ | v • Reply • Share ›

M K Tiwari • a year ago

Thank you so much for the excellent article. I have a question related to your sample code given in the article and the source code "hough_lines.py" that you have at https://github.com/spmallic.... In the sample code I see edges = cv2.Canny(gray, 50, 200) whereas in "hough_lines.py" edges = cv2.Canny(img, th1, th2) where th1 is 500 and th2 is 200(th1 * 0.4). How did you conclude about the values initThresh = 500 and maxThresh = 1000? What if 50 and 200 is supplied to Canny function in hough_lines.py?
Thanks in advance,
Manoj

^ | v • Reply • Share ›