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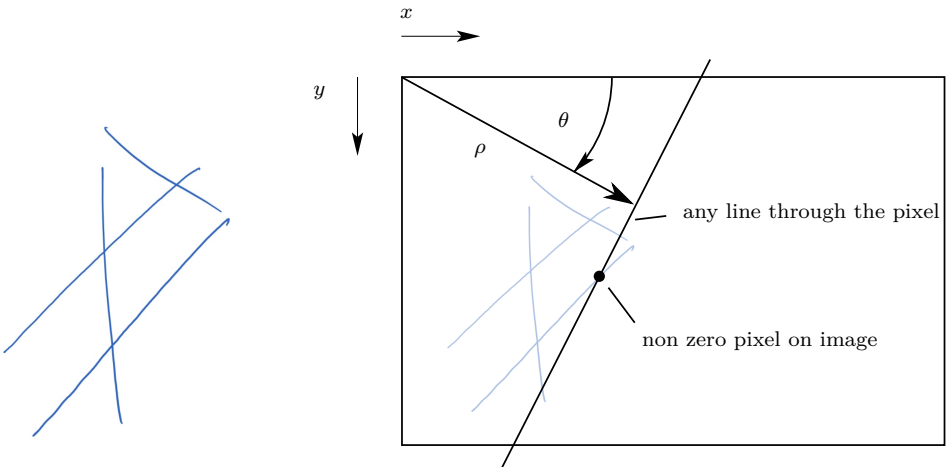
Laboratory – Hough Transform for Lines

Learning goals

- understand the principle of the Hough transform
- can implement the Hough transform for lines
- learn to express a vectorized result from the voting space



(a) Image `handdrawing.tif` **(b)** Image: parameters ρ and θ will address the Hough voting-space.

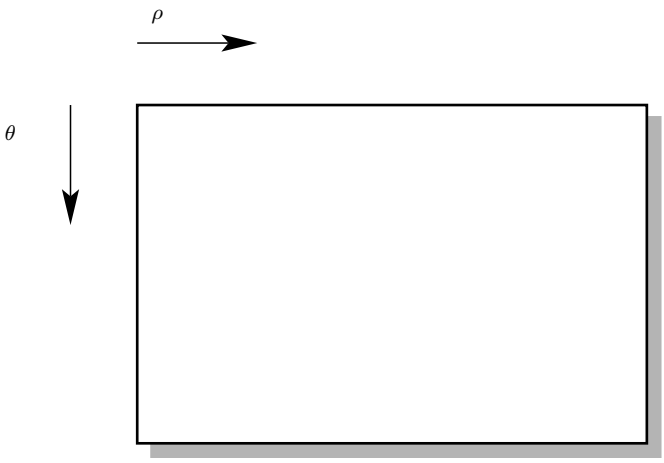


Abbildung 1: Hough voting space.

Introduction

The image `handdrawing.tif` shows some hand drawn lines. The Hough transform shall be used to recognize them. More precisely, straight lines shall be found that approximate them.

Implement the Hough transform for lines $HT_L(\theta, \rho)$. Your implementation should work for binary- as well as grayscale `uint8` images. Before you start implementing the algorithm, answer the following questions for you:

a) Given a gray value $g(x, y)$ at image coordinates (x, y), how do you compute the locations i.e. inclination θ and radius ρ for the respective votes? More specifically, for a given inclination angle θ how do you determine the radius ρ? sqrt(x^2 + y^2) = p

b) What are appropriate ranges for the angle θ and the radius ρ? And what would be an appropriate discrete step for each? Omega = 0 - pi
p = 0 - sqrt(x-max^2 + y_max^2)

c) The parameters θ and ρ address the place in the voting space where to vote. However, the matrix representing the voting space must be addressed with indices ranging from 0 to say n. Think about, how to implement the mapping from parameters to indices and back?

0 - pi = 0 - y_n
0 - sqrt(x-max^2 + y_max^2) = 0 - x_n

1 Exercises

Investigate the prepared code and write additional class methods:

a) Precompute the normal vector for each discrete value of θ. You will need them to compute votes for each nonzero gray value. [1]

b) Define a mapping function from parameters $(\theta,\ \rho)$ to indices in voting space.

c) Write a voting function, that loops through the image pixels and adds a vote for each potential angle θ to the voting space.

d) Run the program and display an intensity image of the voting space.

e) Determine the indices at the peaks of the voting space matrix e.g. via the call `peaks = houghpeaks(H,numpeaks,Name,Value)`. Map the indices of the voting space matrix back to the hough parameters.

f) For each peak, draw the corresponding line on the original image. For this, computing a start point and an end point of each line. These points can be expressed as a linear combination of the normal vector $\boldsymbol{n}$ to the line and its orthogonal, the vector $\boldsymbol{u}$ parallel to the line[2]. Draw the line on the image with the command `cv.line()`, which allows the starting and end the point to lie outside the image borders.

[1] MATLAB uses the column major, Python and C use the row major memory layout. If you want the two components of the vector to be placed in adjacent memory cells, in MATLAB you must put the vectors into a matrix of dimension $2 \times n$, just like in linear-algebra theory. In C and Python it is the other way round.

[2] $\boldsymbol{u} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \boldsymbol{n}$