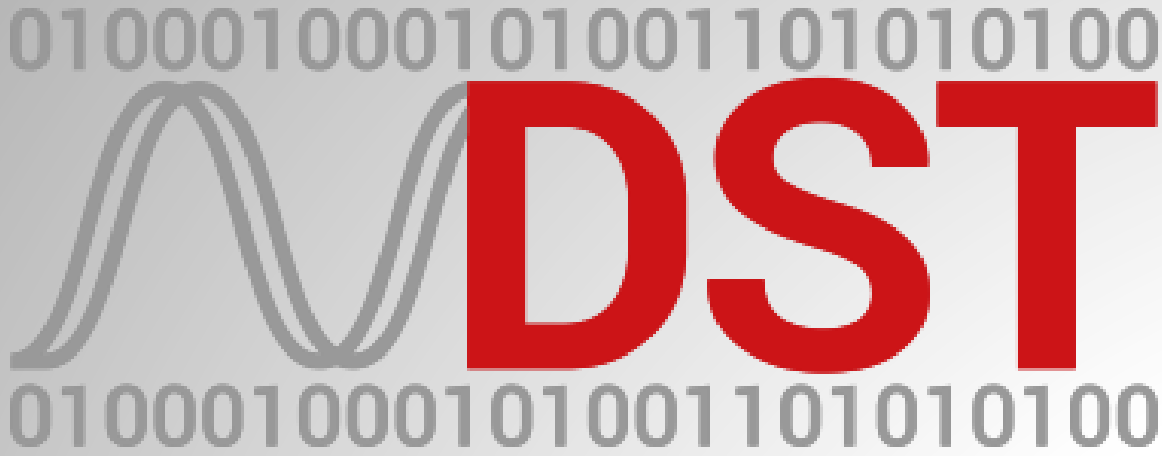
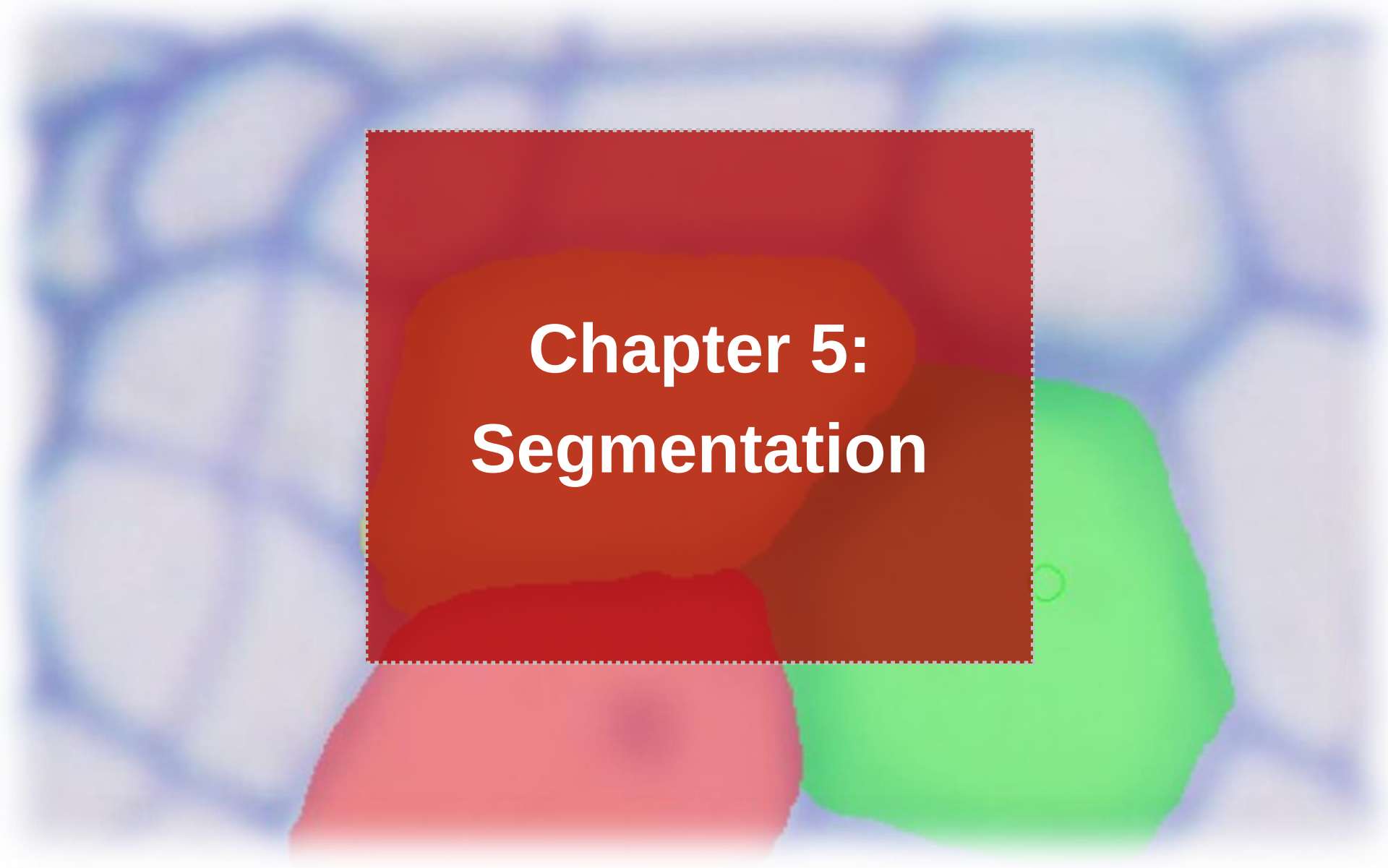




Chapter 5: Segmentation

What is Segmentation?

Segmentation is one of the basic steps in image processing. It links the low level image processing steps with the high level ones.

Definition:

- Separation of the image in partial areas (regions/ segments) with same properties

Application:

- Separation of foreground from background and vice versa
- Extraction of objects

Properties:

- Complete: every pixel belongs to at least one segment
- Overlap free: every pixel belongs to at most one segment
- Coherence: every (foreground-) segment builds a coherent (connected) object

- Using model information in the segmentation process for higher robustness

Template Matching

(1) Define a pattern p(k,l) (called Template) in a way that shape and orientation of the segment is similar in the image g(x,y)

(2) Determine normalized cross correlation function:

$$c(x,y) = \frac{\sum_k \sum_l g(x+k, y+l) p(k,l)}{\sqrt{\sum_k \sum_l g(x+k, y+l)^2} \sqrt{\sum_k \sum_l p(k,l)^2}}$$

indices k and l are only applied in regions, where g(x+k,y+l) and p(k,l) are overlapped

(3) The segments are on the local extremal points of c(x,y)

Properties:

- very easy to apply
- suffers from noise and invariances (rotation, scaling, illumination, etc.)
- only possible, when it is clear how the searched-for object looks like (in reality often not)

Example: Template Matching

Hough Transformation

Main Idea:

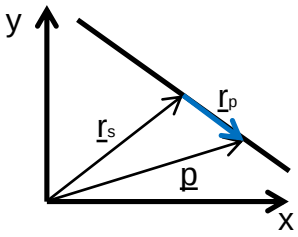
- Detect geometrical shapes (e.g. straight lines, circles, ellipses) in images by transferring them into a special parameter space

Theoretical Background:

- Search straight lines in a binary image b(x,y)
- Using this line equation:

$$\underline{p}^T \cdot \underline{n} = d$$

  - ➢ Hessian normal form
  - – $\underline{n}$ – normal vector ⊥ on the straight line with the length ||n||=1 and the angle φ to x-axis → $\underline{n}\begin{pmatrix}\cos\phi\\ \sin\phi\end{pmatrix}$
  - – $\underline{p}$ – position vector of all line points
  - – d – distance of the line to the point of origin



$$\underline{p} = \underline{r}_s + \underline{r}_p$$

$$|d| = \|\underline{r}_s\|$$

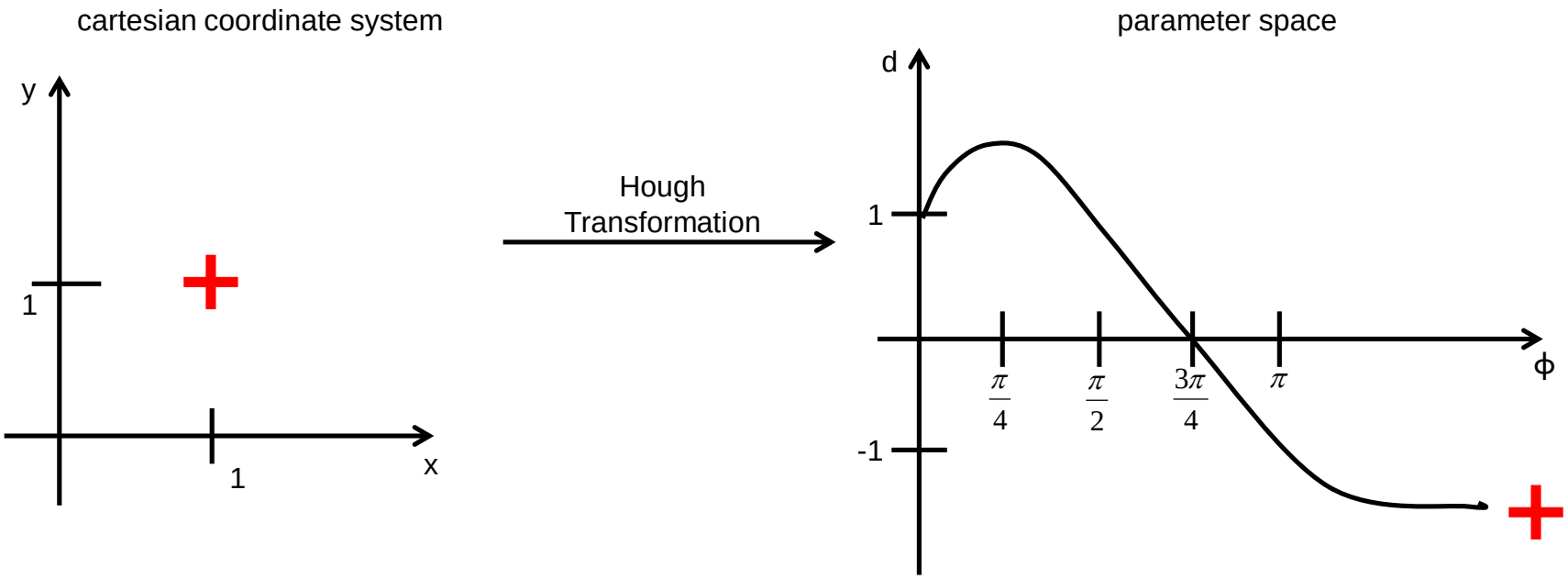
  - – in consequence: $x\cos\phi + y\sin\phi = d$

- coordinate transformation:
  - All straight lines touching the points $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in the cartesian coordinate system will be represented in the (φ,d) - coordinate system with a curve

➢ $H_k : x_k \cos\phi + y_k \sin\phi = d$

Algorithm:

(1) Transformation of all foreground pixels $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in image g(x,y) to the corresponding curves H_k in the (φ,d) – parameter space

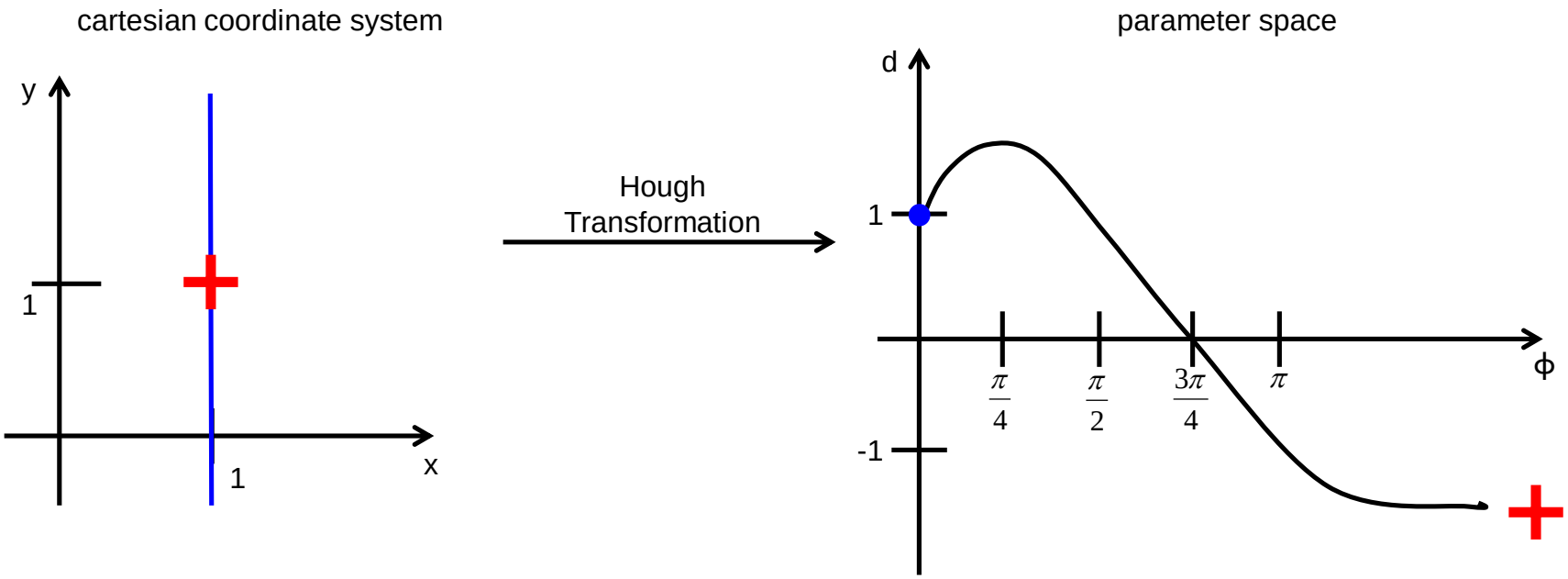


- coordinate transformation:
  - All straight lines touching the points $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in the cartesian coordinate system will be represented in the (φ,d) - coordinate system with a curve

➢ $H_k : x_k \cos\phi + y_k \sin\phi = d$

Algorithm:

(1) Transformation of all foreground pixels $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in image g(x,y) to the corresponding curves H_k in the (φ,d) – parameter space

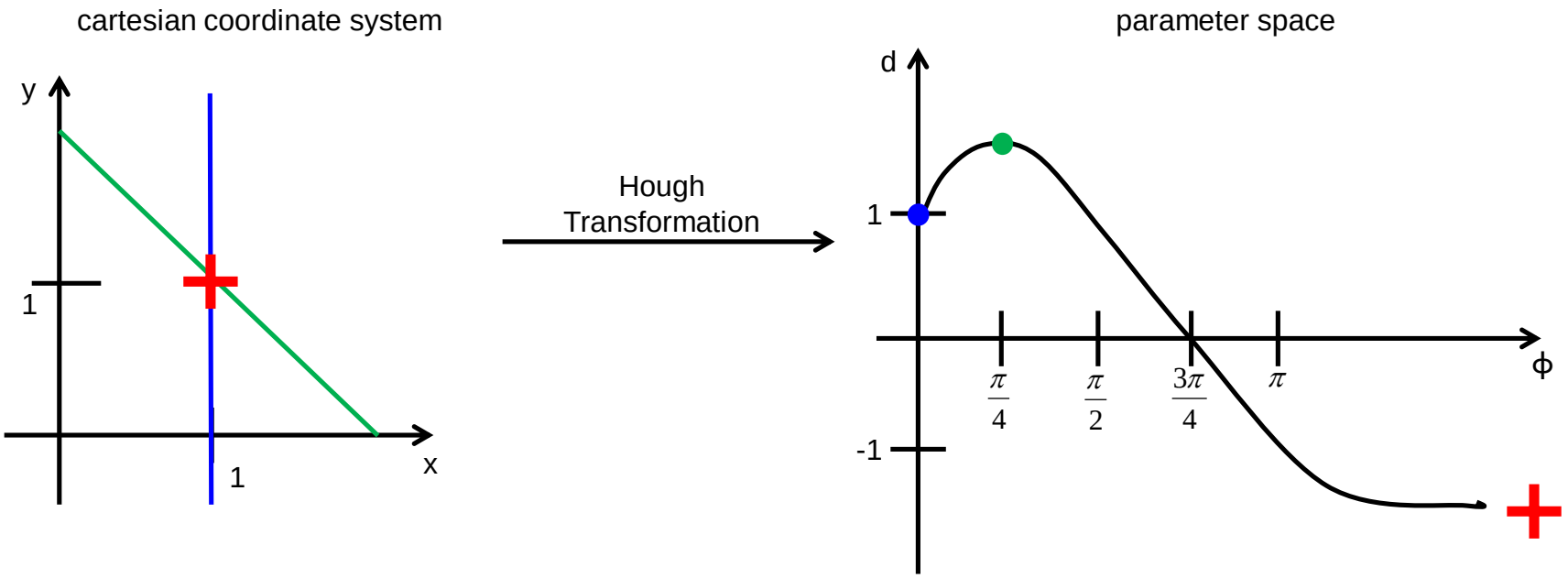


- coordinate transformation:
  - All straight lines touching the points $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in the cartesian coordinate system will be represented in the (φ,d) - coordinate system with a curve

➢ $H_k : x_k \cos\phi + y_k \sin\phi = d$

Algorithm:

(1) Transformation of all foreground pixels $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in image g(x,y) to the corresponding curves H_k in the (φ,d) – parameter space

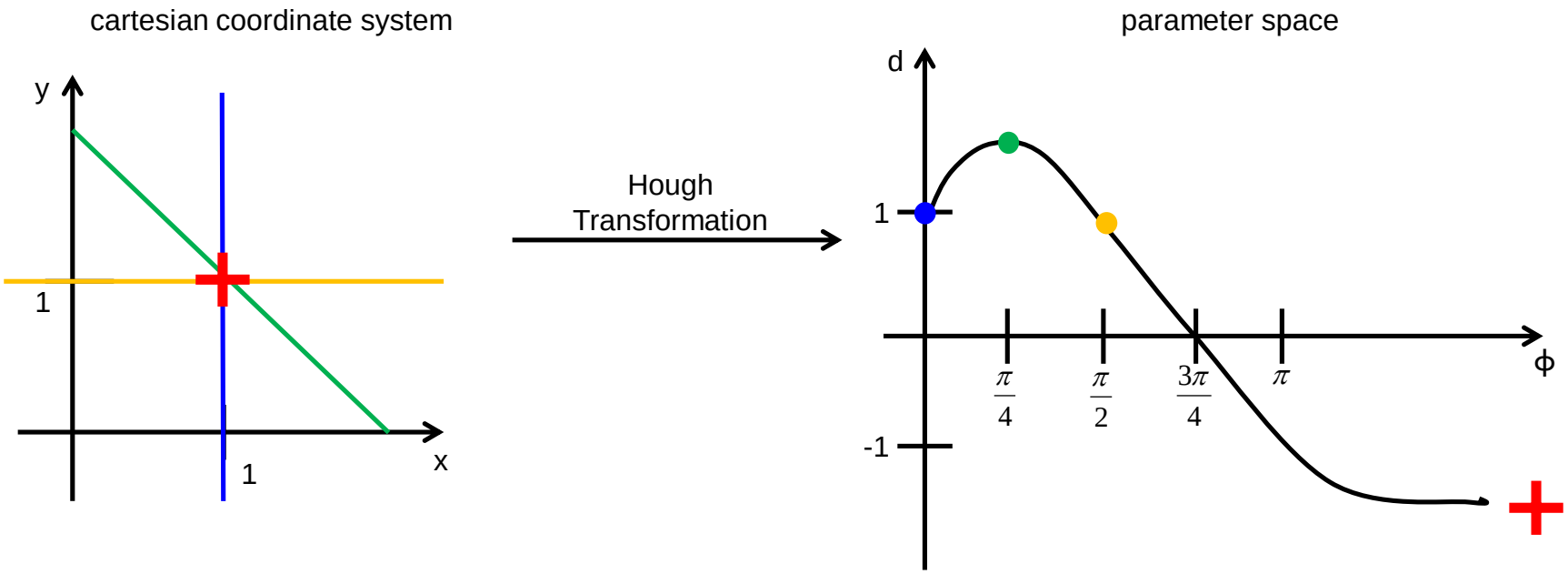


- coordinate transformation:
  - All straight lines touching the points $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in the cartesian coordinate system will be represented in the (φ,d) - coordinate system with a curve

➢ $H_k : x_k \cos\phi + y_k \sin\phi = d$

Algorithm:

(1) Transformation of all foreground pixels $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in image g(x,y) to the corresponding curves H_k in the (φ,d) – parameter space

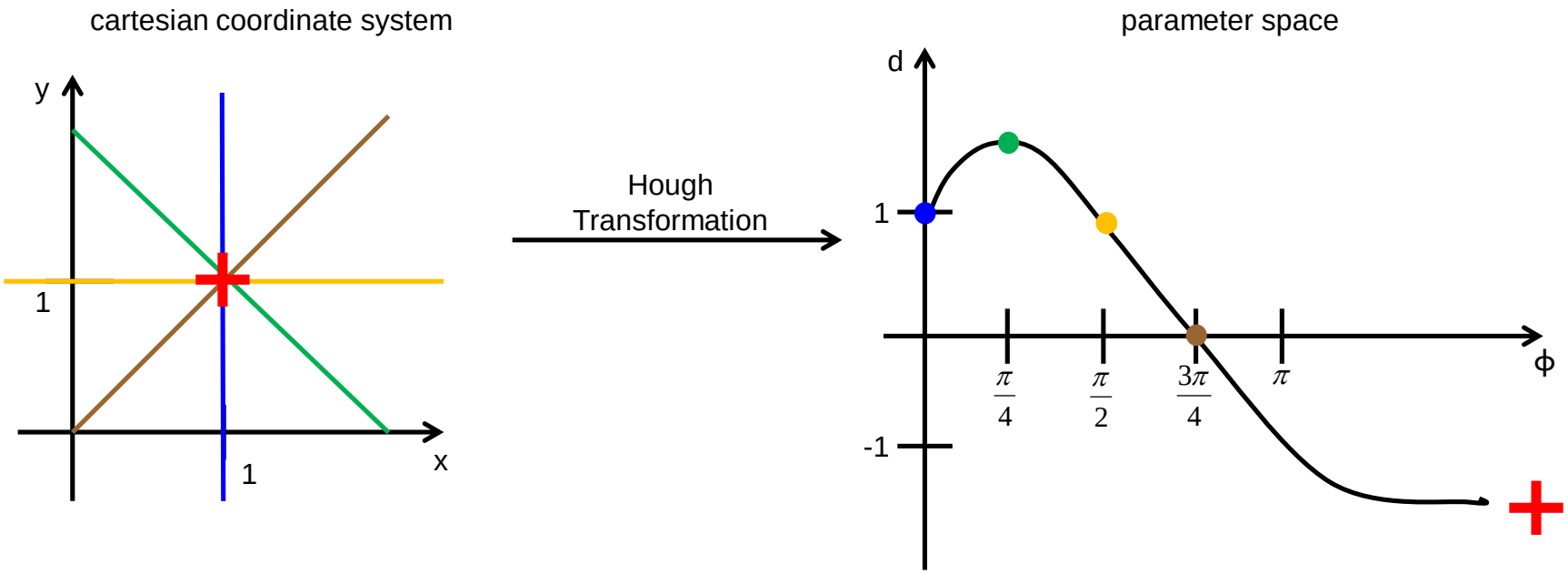


- coordinate transformation:
  - All straight lines touching the points $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in the cartesian coordinate system will be represented in the (φ,d) - coordinate system with a curve

➢ $H_k : x_k \cos\phi + y_k \sin\phi = d$

Algorithm:

(1) Transformation of all foreground pixels $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in image g(x,y) to the corresponding curves H_k in the (φ,d) – parameter space

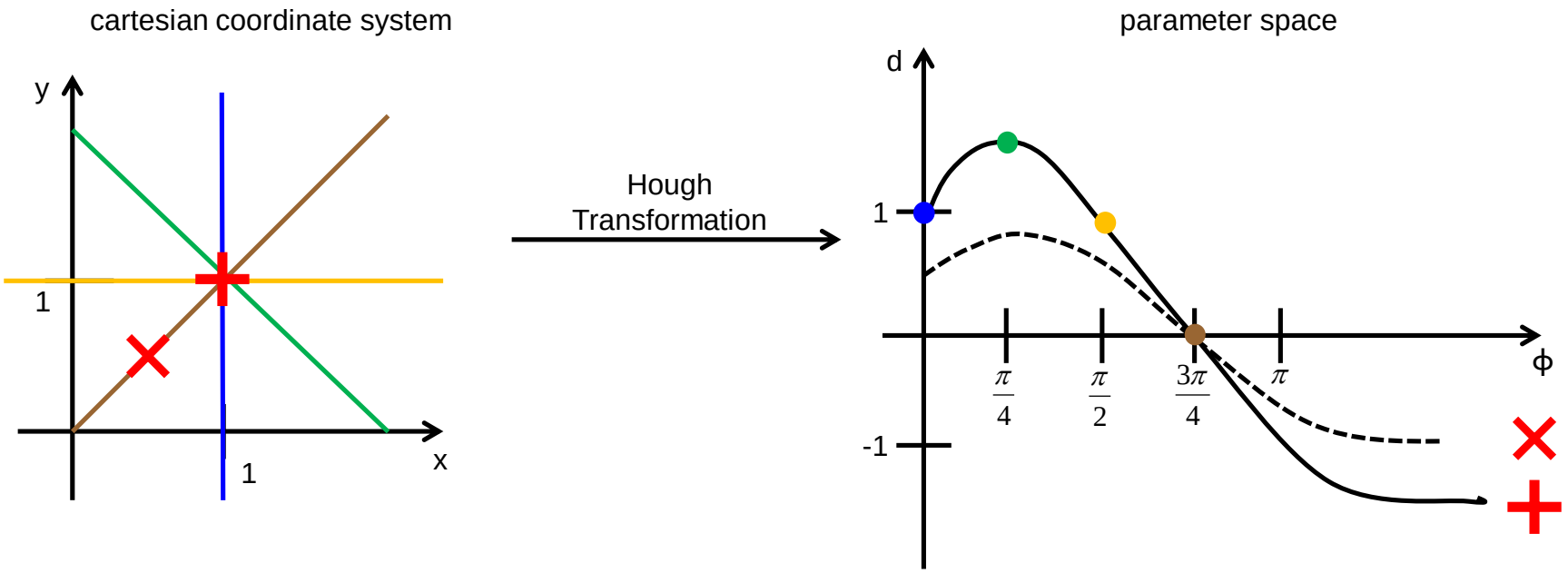


- coordinate transformation:
  - All straight lines touching the points $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in the cartesian coordinate system will be represented in the (φ,d) - coordinate system with a curve

➢ $H_k : x_k \cos\phi + y_k \sin\phi = d$

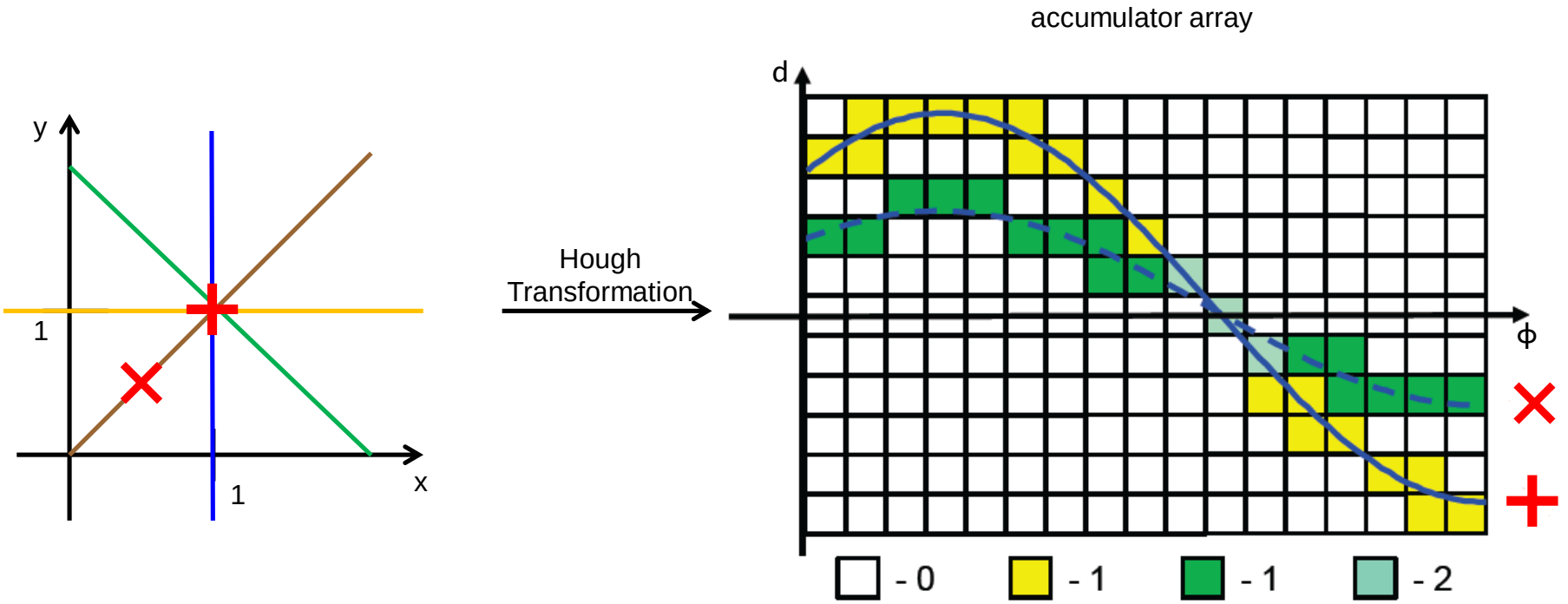
Algorithm:

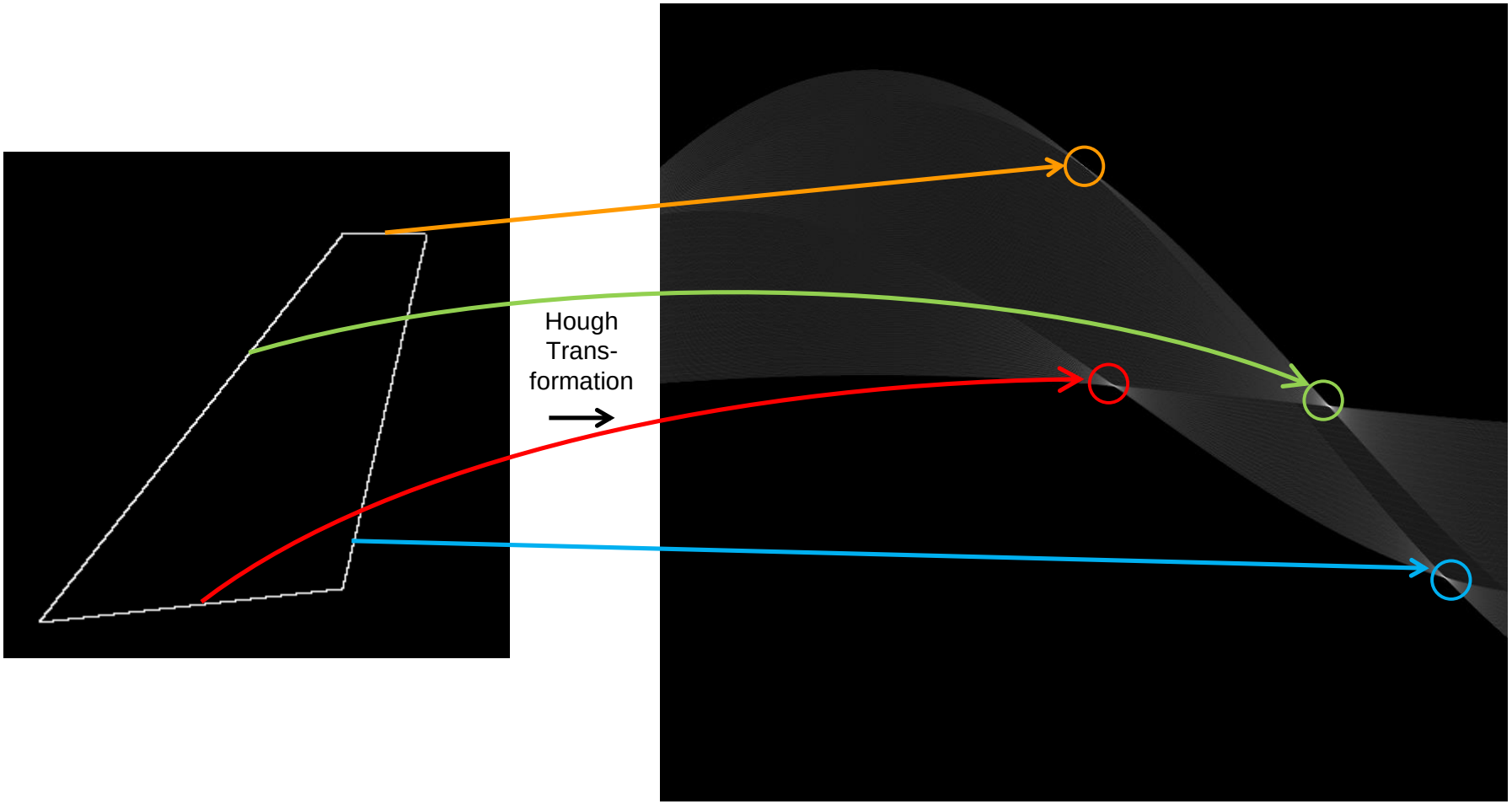
(1) Transformation of all foreground pixels $\underline{p}_k = \begin{pmatrix} x_k \\ y_k \end{pmatrix}$ in image g(x,y) to the corresponding curves H_k in the (φ,d) – parameter space



(2) Search for points in the (φ,d) - parameter space, where many curves H_k are intersecting

- for easy implementation use accumulator array
- every foreground pixel p_k creates a curve H_k and increases corresponding bins of the accumulator array by 1
- intersections of several curves H_k increase the same bins multiple times
- straight lines are at coordinates corresponding to local maxima in the accumulator array





[Source: Tönnies, „*Grundlagen der Bildverarbeitung*“]

Fifth Exercise

- Implement Template Matching via Cross Correlation
  - Straightforward use of formula
  - Do this exercise first
  - Solution will be revealed on 26 June

- Implement Hough Transformation for straight lines
  - Start this right after Template Matching, don‘t wait for the solution!
  - If you are confused, try drawing a minimal example on paper
  - Solution will be revealed on 3 July

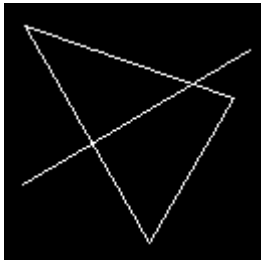
Expected Output (Template Matching)

Cross Correlation Image

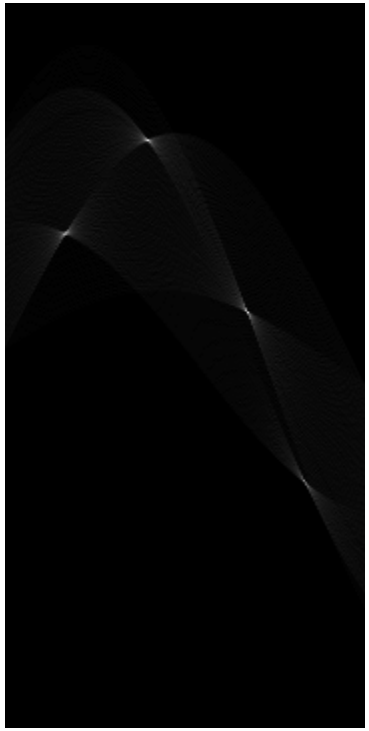
Matched Template

Expected Output (Hough Transformation)

Straight Lines



Hough Transformation



Detected Lines