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Object Detection on Images Captured by CCD-Camera

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Corner detection of static object

First step of any image processing system is acquisition of image. It is a process where analog optical inputs are converted to electrical signal. Next step is processing of input image by applying color filtering and binary mathematical morphology.
Finally, after line detection using Hough transform, corners of static object can be detected. These can be used for different applications, like object measuring, distance measuring and more.

Figure 1. Scene with the object (box)

Color model

RGB model - Colors in RGB model are produced by additive approach. That means, by adding maximum values of all three basic RGB components, white color is produced. Disadvantage of this color model is that it does not separate color and brightness.

HSV model - Basic elements of HSV model are hue, saturation and value (brightness). Interpretation of colors in HSV model is similar to how human eye interprets colors.

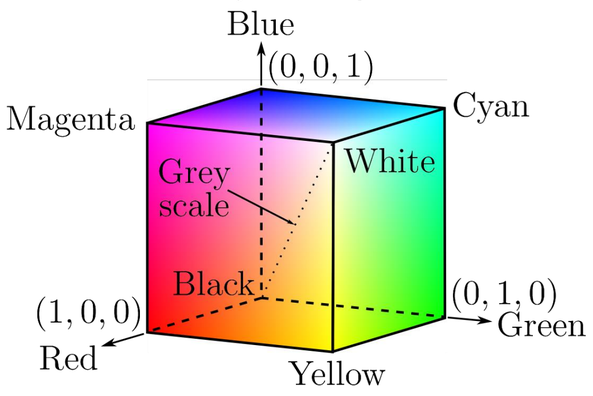

Figure 2. RGB model

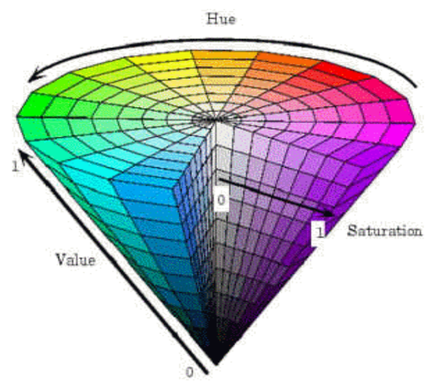

Figure 3. HSV model

Color filtering - After converting RGB model to HSV model, ranges of HSV elements can be set to filter out all colors except brown color of the object. Result of this step can be seen in the following figure.

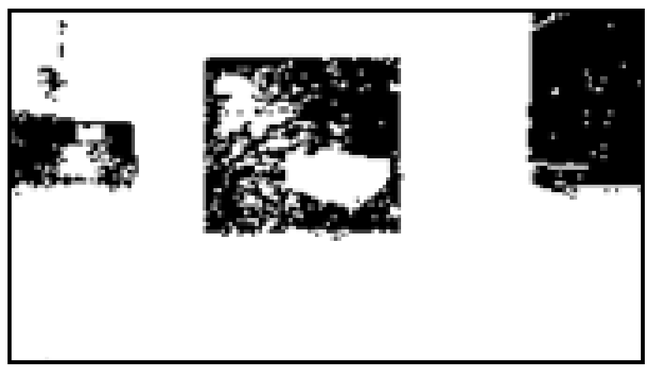

Figure 4. Binary mask of the object after applying ranges of HSV elements

Binary Mathematical Morphology

Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. Morphological techniques probe an image with a small shape or template called a structuring element. Fundamental operations of binary mathematical morphology are **erosion** and **dilation**.
Erosion is based on vector difference.

$$A \ominus B=\{p \in \varepsilon^2: p + b \in A \text{ for each } b \in B\}$$

Each point of image *p* is tested if outcome for all *p* + *b* is located in *A*. If it is then output for that point is 1 or 0 if it is not located in *A*.
Dilation is a dual operation to erosion, both operations are not invertible.

$$A \oplus B = \{p \in \varepsilon^2: p = a + b, \ a \in A, b \in B\}$$

It is a point set of all possible additions for pair of pixels, one from set *A* and other from set *B*.

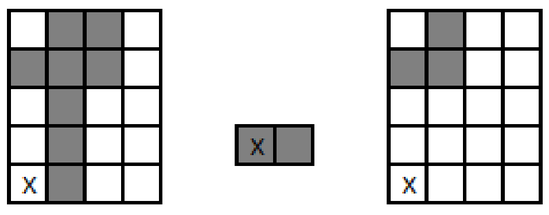

Figure 5. Erosion

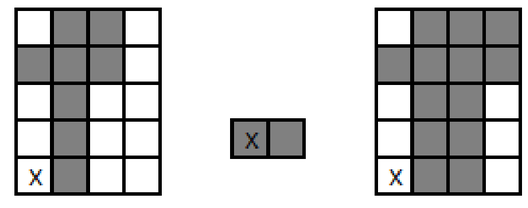

Figure 6. Dilation

Combination of both operations with suited structuring elements is used to filter out noise and backgroud from our binary mask and detect edges of the object.

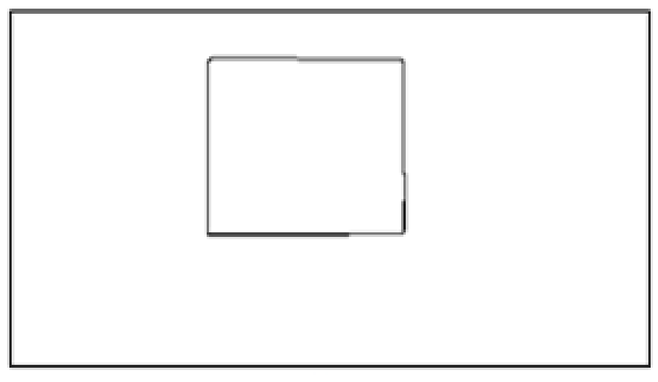

Figure 6. Boundaries of the object

Hough transform

The simplest case of Hough transform is detecting straight lines. In general, the straight line y = mx + b can be represented as a point (b, m) in the parameter space. However, vertical lines pose a problem. They would give rise to unbounded values of the slope parameter m. Thus, for computational reasons, Hesse normal form is used.

$$r = x \cos(\Theta) + y \sin(\Theta)$$

where *r* is the distance from the origin to the closest point on the straight line, and Θ is the angle between the *x* axis and the line connecting the origin with that closest point. The final result of the linear Hough transform is parametric plane. Edge pixels mapping to the same Θ and *r* area assumed to define a line in the image.

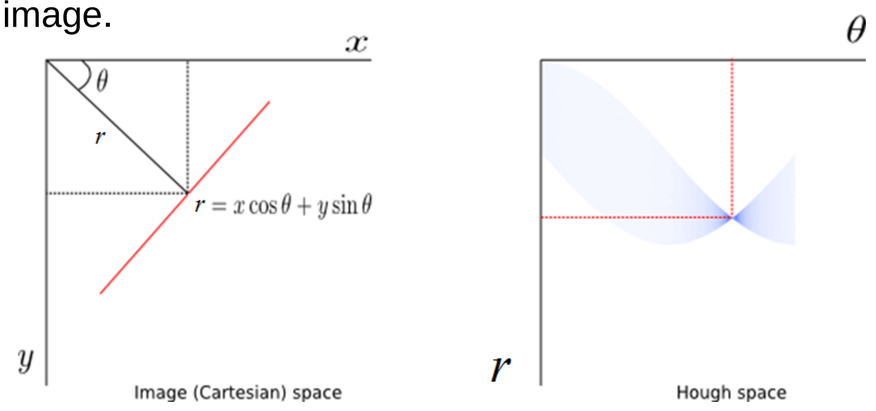

Figure 7. Hough space

Four lines representing boundaries can now by produced by applying Hough transform to the edge binary mask (Fig. 11) and choosing four most frequent parameters. Edges of the object are produced by computing intersections of those four lines.

Figure 8. Corners of the object