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Edge Color Distribution Transform: An Efficient Tool for Object Detection in Images

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In this paper, we propose to utilize the color attributes of edge points to construct the Edge Color Distribution Space (ECDS), which can segregate the edges of different objects and keep the spatial relations of the same object as well.

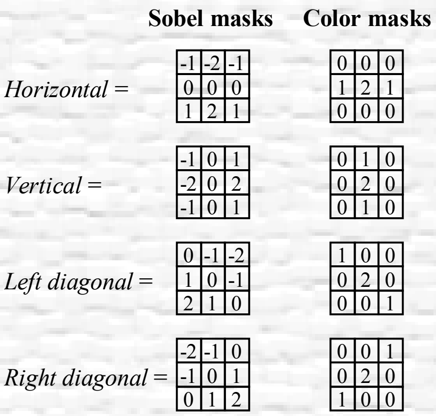
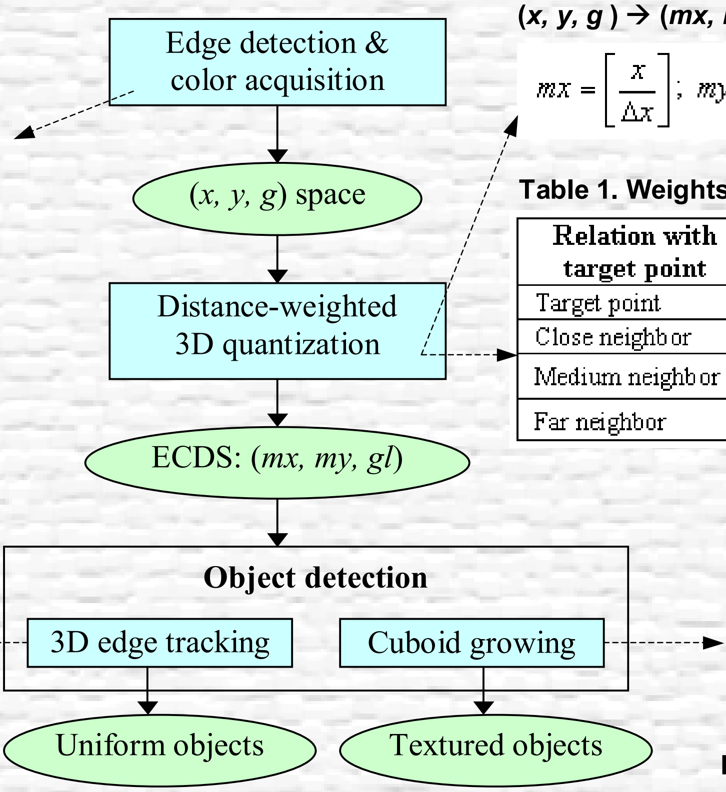


Figure 1. Color operator



(x, y, g) → (mx, my, gl) :

$$mx = \left[\frac{x}{\Delta x} \right]; \; my = \left[\frac{y}{\Delta y} \right]; \; gl = \left[\frac{g}{\Delta g} \right]$$

Table 1. Weights of 3×3×3 neighborhood

Relation with target point	Euclidean distance	Weight
Target point	0	15
Close neighbor	1	5
Medium neighbor	$\sqrt{2}$	4
Far neighbor	$\sqrt{3}$	3

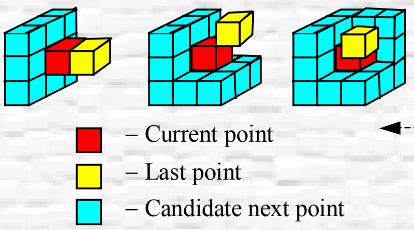


Figure 2. Directional neighbors

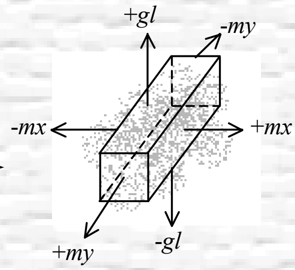
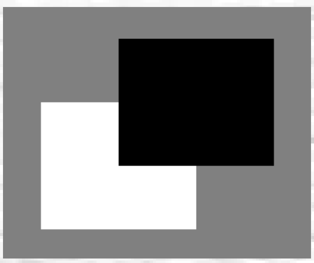
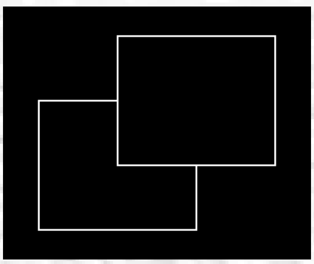


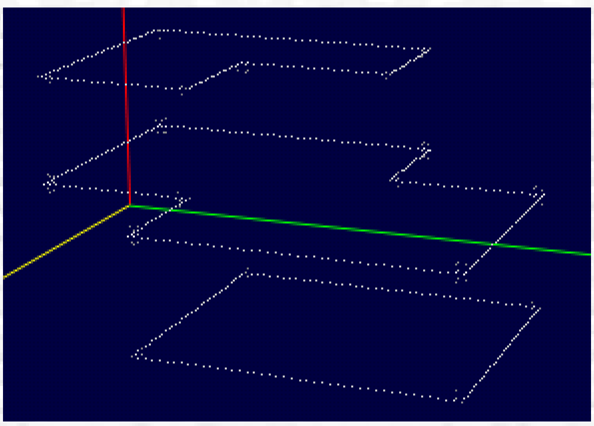
Figure 3: cuboid growing



(a) Original image



(b) Sobel edges

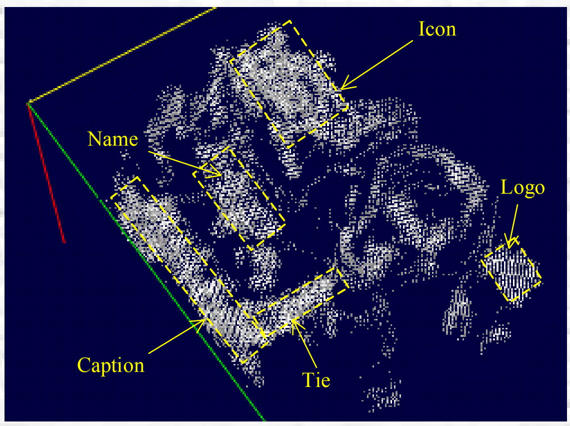


(c) Visualization of ECDS

Figure 4. ECDS of a synthetic image

(a) Original image

(b) Sobel edges



(c) Visualization of ECDS

Figure 5. ECDS of a video image

Notes:

Existing methods for low-level object detection always perform the color-similarity analyses in the 2D image space. Edge is the most often used feature in such analysis. However, the crowded edges of different objects make the detection complex and error-prone, and edges do not carry the color information, which is very useful for separating different objects.

In this paper, we propose to utilize the color attributes of edge points to construct the Edge Color Distribution Space (ECDS), which can segregate the edges of different objects and keep the spatial relation of the same object as well. The whole paradigm is shown as follows.

Firstly, we choose Sobel edge operator to extract the edges since it generates double edges so that each color region owns its edge. To get the smoothed color of each edge point, we design a color operator to work with Sobel operator. It has also four directional masks corresponding to those of Sobel operator. When doing the edge detection, the Sobel operator determines the direction with the maximal gradient for current point. The color mask corresponding to this direction is selected and centered at current point to calculate its color. Thus, after this step, the image coordinates and the color of all edge points form the (x, y, g) space.

The (x, y, g) space is too fine to tolerate the minor color difference and to get good clustering effect. Moreover, the memory requirement for such space is too large. Thus, the distance-weighted 3D quantization is performed to transform the (x, y, g) space to the ECDS (mx, my, gl). Each point transformed to the ECDS will increase the accumulators of both the target point and its neighbors by the weight values defined in Table 1. The distance-weighted accumulation is to minimize this quantization error. The quantization intervals Δx, Δy have a direct impact on the detection rate. Smaller Δx, Δy brings all objects up, while larger ones would only bring the larger objects.

Since the *mx-my* plane is transformed from the image space by linear quantization, the original spatial relation among the edges of an object is kept in ECDS. Due to the color difference, the edges of different objects, which were overlapped or very close in the image space, are segregated. Thus, a clustered part in ECDS always indicates an object, which is not true in the image space.

Since the uniform-color objects and textured objects have very different distribution characteristics in ECDS, they should be detected in different ways. The edges of uniform-color objects are isolated and continuous, so we propose a 3D edge-tracking algorithm to detect them. Since the tracking goes along the edge direction, it is unnecessary to check all connected neighbors, but only necessary to check the directional neighbors that are determined by the local tracking direction (Fig. 2). Because the edges of textured objects cluster in ECDS, we use a cuboid-growing algorithm to detect them (Fig. 3). Detailed algorithms are described in the paper.

Figure 4 shows the ECDS of a synthetic image containing a white rectangle and a black rectangle on the gray background. Two rectangles are partially overlapped (Fig. 4a). Fig. 4b shows the result of edge detection using Sobel operator. The edges of two rectangles touch each other. However, they are totally separated in ECDS, as shown in Fig. 4c. Figure 5 shows an example of real video image. The edges of textured objects are dense so that they are easy to be detected. For example, part 1 is the tie; part 2 is the logo; part 3 is the icon; part 4 and 5 are texts.