3X-07

New Edge Detector for Rotation Invariant Coin Recognition System

Hector SANDOVAL* Sachiko KITAGAWA* Mika SATO* Yasutami CHIGUSA*
Taizoh HATTORI †

1 Introduction

Edge Detection plays a central role in machine vision, serving as the initial pre-processing step for numerous object detection algorithms. New methods are still being developed and it is a open field for research. This importance led us to search for alternative edge detection methods that, as we will explain in this paper, give us alternative ways to solve a specific problem. Along with the description of the method, obtained results are shown and future steps are described.

2 Objectives

Our aim is to show an alternative edge detection method that will allow us to detect borders that fulfill a predetermined condition regarding its orientation. We also pursue the realization of orthogonal edge detector operators that will allow us to not only detect the borders of an image but also decompose the image in its orthogonal components. This research was started when we were looking for alternative pre-processing methods to be used in a rotation invariant coin recognition system.

3 Method Description

Well known operators as Sobel, Laplace or Canny are commonly applied as convolution masks to every pixel of a 2D digitized image function $I = f(x, y)$. Therefore, all the borders (in every possible direction) will be detected. Our proposed method, also based in the use of convolution masks, will detect only those borders that have a specific orientation according to the position of the pixel being analyzed. In other words the method is *position dependent.* The determination of the position is explained with the help of Figure 1.

Consider the digitized image $I = f(x, y)$ with $N \times M$ pixels of size, with a center point C which coordinates are $(0, 0)$. The coordinates (x, y) that gives the position of any pixel P, with respect to the central point C, could be also determined by its polar coordinates (r, θ)

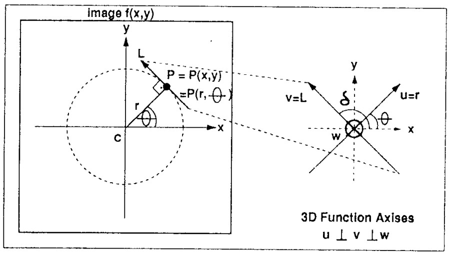

Figure 1: Explanation Diagram.

(with respect to the same central point C). Once we have determined the position of a pixel P, a convolution mask (that will be applied on the point P) of size $R \times R$ is generated. Thus, the values of the convolution mask will depend on the value of the angle θ.

The values of the convolution mask are obtained sampling a 2D (bi-dimensional) function $w = g(u, v)$. The origin of the Cartesian system u, v, w used by $w = g(u, v)$ is placed in the pixel being analyzed. Thus, the axis u and v are co-planar with axis x and y. The direction of axis v has the same orientation as the line L (Figure 1), where L is a tangential line to the circle of radius r in the point P. In other words, the angle δ of axis v (see Figure 1) must be $\delta = \theta + \frac{\pi}{2}$. Dependency of the Cartesian system u, v with respect to the Cartesian system x, y could be described as $u = u(x, y) = u(r, \theta)$ and $v = v(x, y) = v(r, \theta)$.

The conditions given above will produce different convolution masks for every point being analyzed. This convolutions masks, once applied to the image, will detect only those borders that have an angle direction γ, where $\gamma = \delta$,i.e., borders that have the same direction as the axis v of function $w = g(u, v)$. The function $w = g(u, v)$ is called a *generic function* because its shape could be modified to generate well-known masks such as Sobel, Laplace, etc.

4 Simulation and Results

The election of the shape and form of the generic function, was based in values observed in masks such as Sobel and Laplace. This masks could be generated in the same way we are generating our mask: sampling an adequate 2D function. For example, with the cor-

*Tokyo University of Technology, Information Technology Department, Chigusa Laboratory, E-mail: hector@linux.it.teu.ac.jp , URL: http://www.teu.ac.jp/linux/~hector/
†Tokyo International University

rect values chosen, the Laplace mask could be obtained from

$$w = a(u,v) = e^{\frac{(u+\mu)^2+(v+\nu)^2}{D}}. \quad (1)$$

The 2D function used in simulation as an Edge Detector was chosen to be:

$$w = g(u,v) = e^{\frac{(u+\mu)^2+(v+\nu)^2}{D}} - e^{\frac{(u-\mu)^2+(v-\nu)^2}{D}} \quad (2)$$

where μ and ν are parameters that help us to obtain the rotated version of the function $w = g(u,v)$ which will be sampled to obtain the corresponding convolution mask values. We have to note that the rotation of $w = g(u,v)$ is done along the w axis.D is a scaling factor.

Basically, the reason for choosing this function was to give high values to pixels that are part of a border being detected and to attenuate the influence of the other pixels. The chosen function is a composition of two Standard Normal Distribution Functions shown in Equation 1. Furthermore, in our simulations, we have changed the orientation of the function $w = g(u,v)$ by $\frac{\pi}{2}$ generating a new function $w' = g'(u,v)$. In this case the axis u is now co-linear with line L (in Figure 1) and δ becomes $\delta' = \theta + \pi$. Thus, masks generated using $w' = g'(u,v)$ become an orthogonal version of the original ones. The operator still detects those borders with an angle direction $\gamma = \delta$ but now δ has change by $\frac{\pi}{2}$, so the direction of the borders being detected are different from the original ones by $\frac{\pi}{2}$ too. Figure 2 shows the most representative pattern used for testing purposes. Also is shown a comparison between responses using Sobel masks and using masks generated from $g(u,v)$ and $g'(u,v)$ respectively.

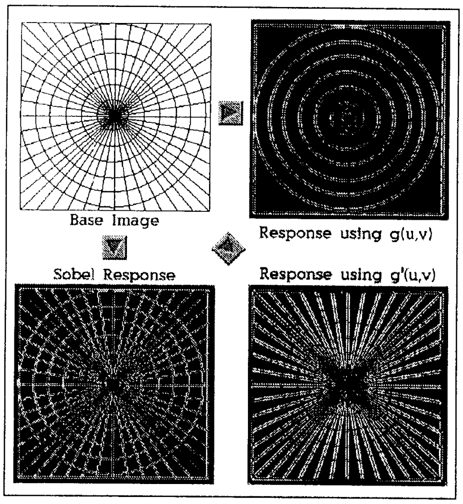

Figure 2: Base Image and its Output Images.

In our simulations we used images of 255×255 pixels with 256 gray-levels. The size of the convolution mask is 5×5 pixels.

5 Discussion and Conclusions

As we see in Figure 2, the results obtained were as expected. The proposed method detects borders according to its orientation and works as a filter too because borders that not have the correct orientation are treated as noise and thus, eliminated. In Figure 2 we can see the orthogonal property shown by images generated using $g(u,v)$ and $g'(u,v)$. Our simulations also included test with real images of Japanese 500 Yen coin (used in [2]). In Figure 3 is shown a comparison between an image using Sobel operator and an image using the proposed method.

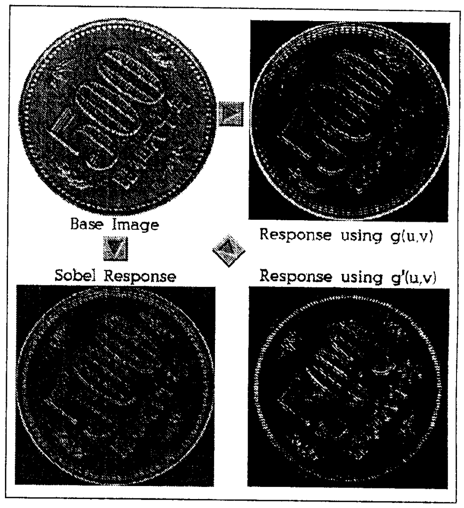

Figure 3: Edge Detected Japanese 500 Yen Coin.

As we can see, noise response in the resultant images is acceptable but we consider that the quality of the response image could be improved varying parameters such as the size of the convolution mask (which influence in noise is considerable) and the values and shapes of the function $w = g(u,v)$. This tests are in develop. Also we mentioned this method is position-dependent. The response using shifted images will be analyzed.

References

[1] Sonka, Hlavac and Boyle, *Image Processing, Analysis, and Vision Machine. 2nd. Ed.*, Brooks-Cole Publishing Company, 1999.

[2] Kitagawa, Sato, Sandoval, Chigusa and Hattori,*Rotation Invariant Recognition System for 500 Yen Coin*, TO BE PUBLISHED in March 2000.