A NEW APPROACH FOR EDGE DETECTION BY USING THE OTF OF THE CAMERA

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ABSTRACT

One of the most investigated problems which exist in image processing is to find the optimal method to extract the different features(edges, regions,...) of the image.
The main source of these problems is the diversity of images because they are obtained under different conditions of illumination and by different sensors.

So a lot of algorithms are proposed to extract these features and any one of the algorithms gives good results in all cases with all images. So the idea is to find an algorithm which depends only on the used camera as the **OTF** (Optical transfer function). The majority of methods are based on the relation :

$$\text{Image output} = \text{Image input} * \text{filter}$$

So

$$\frac{\partial^2 \text{Image output}}{\partial x \partial y} = \text{Image input} * \frac{\partial^2 \text{filter}}{\partial x \partial y}$$

In practice we use directly the second relation, we apply a convolution product between the image and a mask, in reality the coefficients of the mask are the derivative coefficients of the filter.
This relation shows that the image is always forced to be filtered with a certain filter as gauss filter, mean filter, ...etc . In reality the final contour image is not of the original image but it is the contour of the filtered image. So my method is different, I use a relation which is obtained with image restoration model including the OTF function.

KEY WORDS

Extraction of edge , Convolution, Optical transfer function, modulation transfer function, [1]phase transfer function.

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1- INTRODUCTION

In this paper, I have not to compare this method with all methods which use the convolution product [1] by forcing the neighbourhood of a pixel to follow a certain distribution function (gauss, uniform,...) [2] because it is very difficult to calculate the exact statistical model of the neighbourhood. The best method which is really applied to detect the edges is the Canny –Deriche method [3] [4] , the expression of the filter is calculated by maximising the product of the efficient and localisation coefficients. This method has taken, as a hypothesis, that the noise is gaussian and the edge is a jump edge. Generally the results are successful , but the fundamental problem of this method is to find the best value of the parameter α given in the expression of the derivative filter.

$$f(x) = -k\,x\,e^{-\alpha |x|}$$

2- OPTICAL SYSTEM MODEL

The optical system of a camera is described by relation (1) (Fig.1).

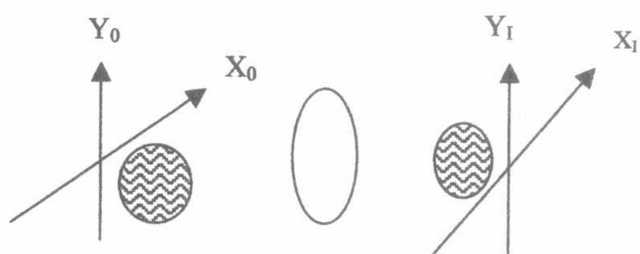


Fig.1. Optical system model

The relationship between the image intensity and object intensity for the optical system can then be represented by the superposition integral equation [5] :

$$I_i(x_i, y_i) = \int\int_{-\infty}^{+\infty} H(x_i, y_i; x_o, y_o)\, I_o(x_o, y_o)\, dx_o dy_o \quad (1)$$

Where $H(x_i, y_i; x_o, y_o)$ represents the image intensity response to point source of light. Often the intensity impulse response is space invariant and the input–output relationship is given by the convolution equation

$$I_i(x_i, y_i) = \int\int_{-\infty}^{+\infty} H(x_i - x_o, y_i - y_o)\, I_o(x_o, y_o)\, dx_o dy_o \quad (2)$$

Normalizing the Fourier transform of I_i, H and I_o we obtain :

$$I_i(\omega_x,\omega_y) = H(\omega_x,\omega_y).\ I_o(\omega_x,\omega_y) \quad (3)$$

$H(\omega_x,\omega_y)$ is called the optical transfer function (OTF) and is defined by :

$$H(\omega_x,\omega_y)= \frac{\int\int_{-\infty}^{+\infty} H(x,y)\ exp(-i(\omega_x x+\omega_y y))dx\ dy}{\int\int H(x,y)dxdy} \quad (4)$$

The absolute value $|H(\omega_x,\omega_y|$ of the OTF is known as the modulation transfer function (MTF) of the optical system.

The most common optical image formation system is a circular thin lens . Fig.2 illustrates the OTF for such a lens as a function of its degree of misfocus . For example misfocus of OTF will actually become negative at some spatial frequencies. In this case the lens will cause a contrast reversal , dark objects will appear brighter and vice versa.

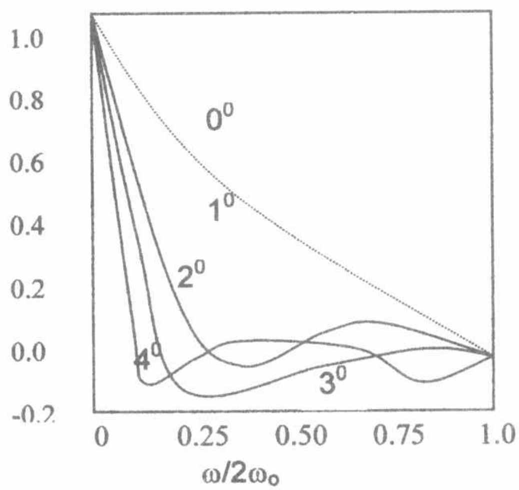


Fig. 2. Examples of MTF

The MTF is a parameter that basically describes how the contrast in the image of sinewave grating (ie a target where the radiant intensity varies sinusoidally in the direction perpendicular to the bars of grating) is attenuated as a function of spatial frequency (ie reciprocal of the period) of the grating . It can be defined as the ration (image contrast)/(target contrast) where contrast is defined as $(I_{max}-I_{min})/(I_{max}+I_{min})$ and I_{max} and I_{min} being respectively the maximum and minimum intensities in the target or its image.
An alternative and equivalent definition is that it is the modulus of the Fourier transform of the LSF(line spread function) of the camera, where the LSF is the one dimensional intensity distribution across the image of narrow line target. Fig.3 illustrates these definitions and shows a typical MTF curve.

The OTF is a complex function (the Fourier transform of the LSF) and includes a phase term, the phase transfer function (PTF) which is the argument of the OTF as well as its modulus, the MTF.

3- EXPERIMENTAL COMPUTATION OF OTF

There are two methods to obtain the OTF ([6] and [7]) :

1- a narrow slit object is used, the luminance image of the to object is taken , we plot the variation of the luminance in the image, this gives the LSF function in one direction (x for example). We repeat the same operation in the other direction we obtain the LSF function in y direction. We can take as a hypothesis that the camera has a circular lens so $LSF_X = LSF_Y$. Taking the Fourier transform of the of each LSF, we obtain the OTF function (look Fig.3).

2- taking an image of a sinewave object (sinusoidal variation of luminance) of known spatial frequencies and measure luminance variations from peak to peak. The MTF can be plotted from these variations as a function of spatial frequencies. We compute the ration for each frequency :

$$\text{Contrast} = I_{max} - I_{min} / I_{max} + I_{min}$$

MTF = (Image contrast)/ (Object contrast)

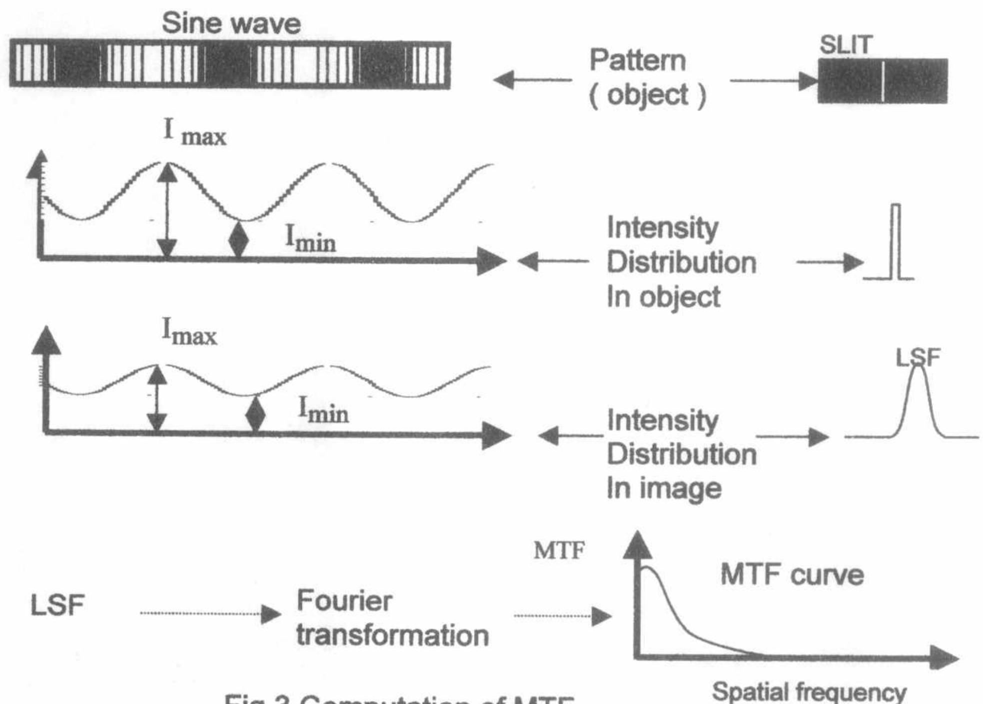


Fig.3 Computation of MTF

The convolution product between image and OTF can be used to extract edges with the same parameter in all cases .

4- RESULTS

The following figures (Fig.4 and Fig.5) show only a few number of results tested with our algorithm, and this method has given a very successful results(images and the inverse of gradient).

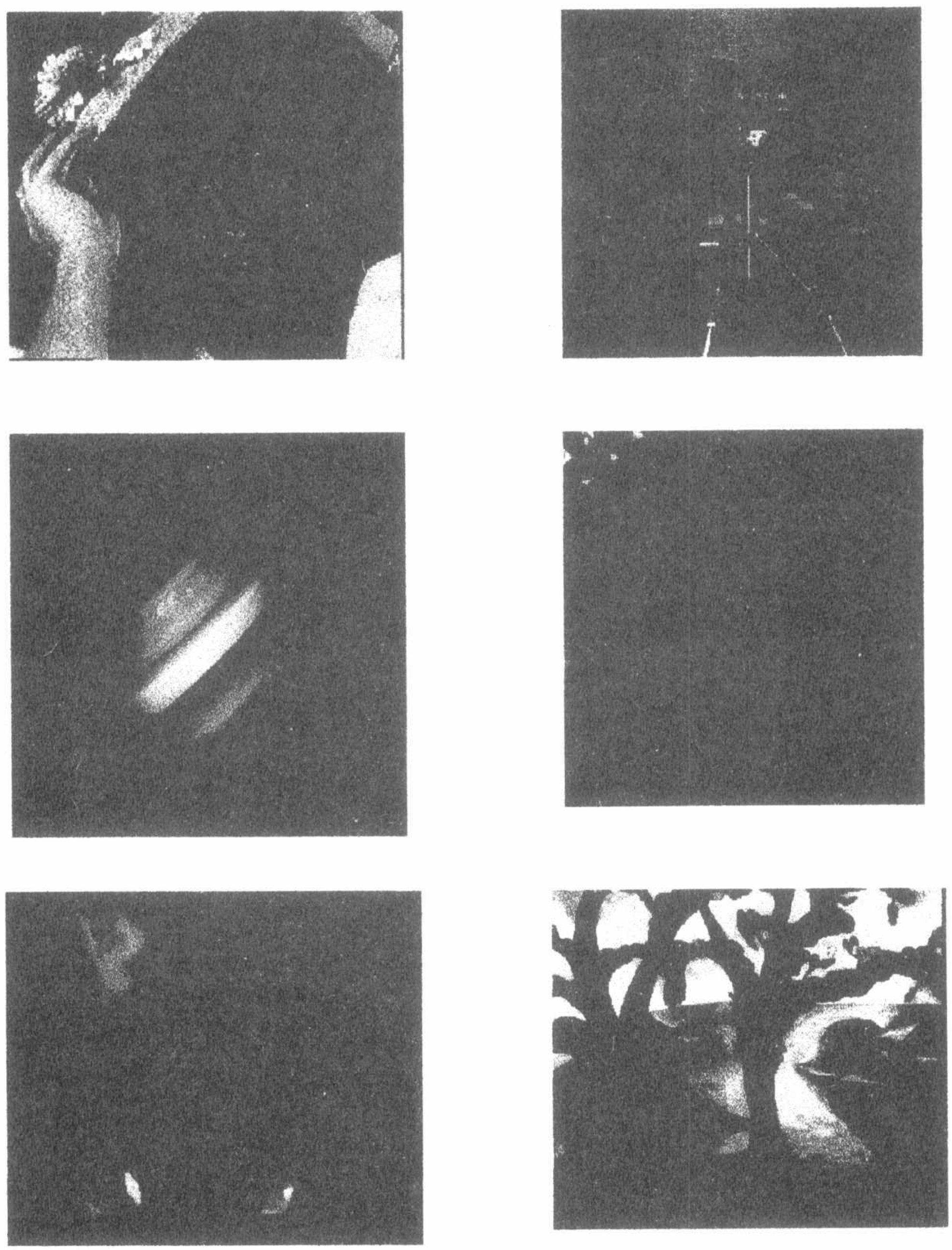
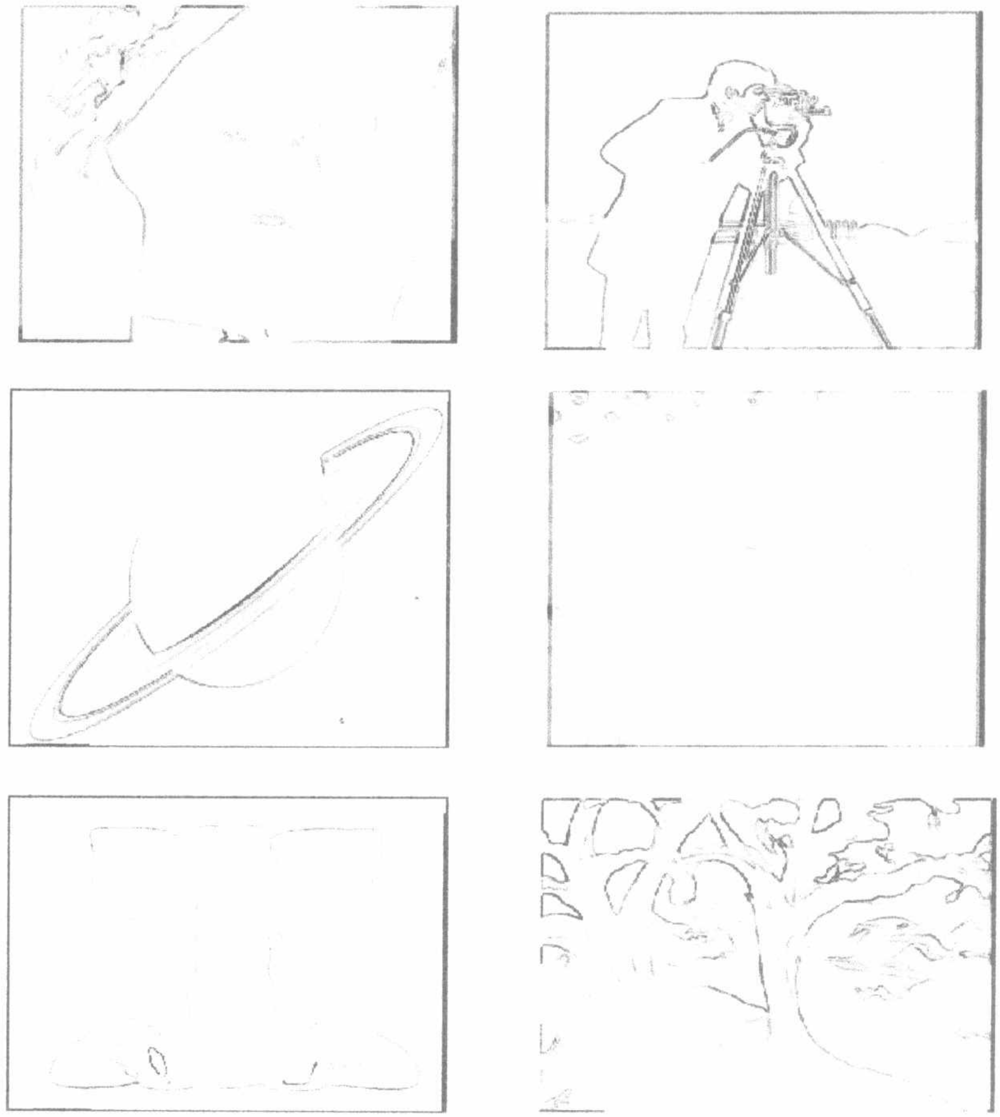


Fig4. Original images



[2]Fig5. Edge of original images

5- CONCLUSION

We have proposed a new approach for edge detection by using the optical transfer function, this method necessitates to compute the OTF of the camera just once, and does not depend on any other parameter . The results obtained with this method are comparable with the Canny-Deriche method when we know that this method **depends essentially on the parameter α.**

Our method does not suppose hypothesis on the statistical model on the neighbourhood of a pixel .

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