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Subpixel Accurate Edge Coordinates Deduction Of Circular Object In Machine Vision

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Abstract: Automation in industries needs faster approach for object inspection. So, for such applications we generally go for machine vision. But, accuracy is also very important. Pixel accuracies are sometimes insufficient to describe the exact dimensions of an object or fall short. In such cases, there is an urgency to device a method which will take care of subpixel accurate measurements. Here, we have come up with such a novel approach to find subpixel accurate edges of a circular object. This we achieved by exploiting local pixel intensity values. Subpixel order of 20th was easily achieved i.e. measurements up to 20 times that of a pixel could be made. We achieved measurements up to 30 microns.

Keywords: subpixel accuracy, edge pixels, subpixel coordinate space

1. INTRODUCTION

Dimensions are required to define any object. And to get dimensions, measurements are necessary. For making these measurements we will go for machine vision using local pixel intensities. Many research has been made in subpixel Measurements but many of them had many shortcomings in terms of accuracies, the methods being not suitable in all conditions or being complex. In moment based method [3] by Edward and Li [4], the rotation of object was necessary but such a thing we can't implement in industrial applications; where object to be inspected moves over conveyer in lateral fashion. The accuracy in Pap[5] is 0.11mm which is very less than what we got in this method. The methods using moments Zheng[6],Ghosal[7] and Wen[8] computationally overloads the system and lacks in repeatability. Hence, there is a need to get measurements more accurate, without rotating the object and getting repeatability. We got accuracy up to 30 microns. Here, the first aim is to achieve pixel accurate edge and for this canny [1] (with σ=1.4) method is used. For getting a subpixel accurate edge, it was our first need to get pixel accurate edge. Once this was achieved, we exploited local edge pixel intensities and deduced the coverage of pixel by each edge using mathematical reasoning and histogram pattern. Also, this method finds subpixel accurate coordinates without rotating the object, so edge pixel location in pixel coordinate space is also taken into consideration. And by theoretical calculations and empirically, we deduced the relationship between the actual subpixel coordinates and pixel coordinate space. On verifying this with experiments, we got subpixel order or subpixel factor up to 20.

II. ASSUMPTIONS

Assumptions made for deducing method for subpixel measurements are as enlisted below:

- Intensity value of a pixel is directly proportional to the pixel coverage by the object.
- All the distances (in pixels) are made assuming centre of pixels as a reference.

III. PIXEL ACCURATE EDGE DETECTION

For subpixel measurements, first it is necessary to get pixel accurate edge. For this purpose, we used canny's algorithm [1] (with σ=1.4).Fig.1 and fig.2 shows the pixel accurate edge and it's histogram respectively, which we'll need for classification of intensities in next step of our method. The histogram shows the maximum and minimum intensities of edge pixels as detected by canny's edge detection algorithm. We can see that the edge pixel intensities varies from 60 to 248.This range we will use later on for classification of intensities into various classes for pixel coverage by edge calculations. The image was captured by 640 X 480 resolution camera.

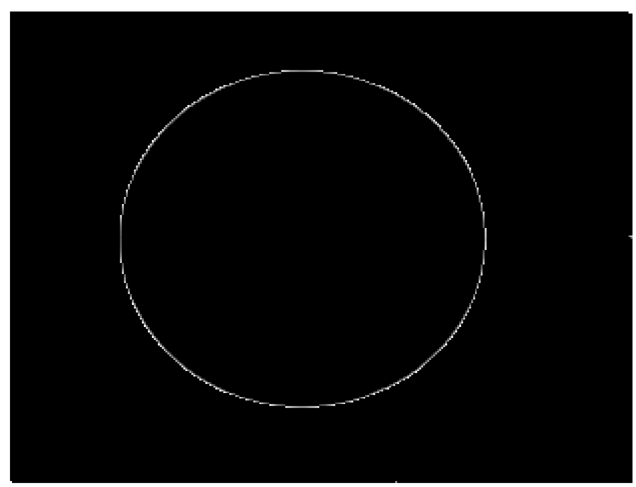

Fig.1 *Edge detected by canny's algorithm (640x480)*

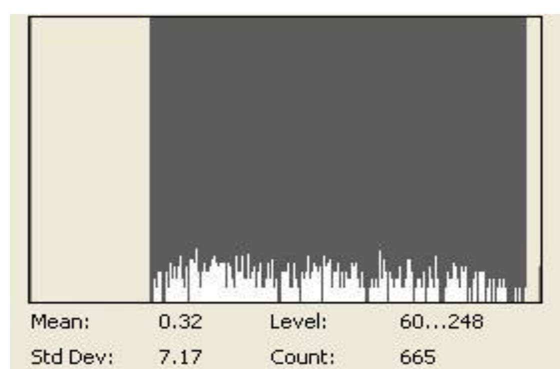

Fig.2 *Histogram for detected edge*

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IV.GROUPING INTENSITIES INTO CLASSES

The edge intensity values depicted by the histogram are divided into various classes, here we have taken 100.the width of each class is calculated as illustrated below. Besides, the various parameters like maximum and minimum intensities are also mentioned.

Example (for above edge):
Max Intensity (I_{max}) = 248
Min. Intensity (I_{max}) = 60
Total divisions to be made = 100
Width of each class = (I_{max}-I_{min})/100
= (248-60)/100
= 1.88

Table.1 *Grouping pixel intensities*

INTENSITY VALUES	CLASS	COVERAGE (%)
60-61.88	1	100
61.88-63.76	2	99
63.76-65.64	3	98
65.64-67.52	4	97
.	.	.
.	.	.
.	.	.
.	.	.
246.12-248	100	1

IV. SUBPIXEL COORDINATE DEDUCTION

From fig.3 we can see the representation of various parameters in pixel coordinate space. We can see the edge pixel for which is taken as reference for calculating subpixel coordinates. For, these measurements we take centre of pixels as the reference. Dx and Dy are x and y coordinates with respect to centre in pixel coordinate space. Let δx and δy be the x and y distances respectively within the edge pixel under consideration. Here, δx and δy will give us the subpixel accurate coordinates in pixel coordinate space. So, our aim is to calculate their values. From the calculations of Dx and Dy, get the values of D and F. Here, F is the number of grids (subpixels) contained in one pixel assuming the pixel is divided into D X D matrix. D being the addition of Dx and Dy. The mathematical deductions are as follows.

$$D = D_X + D_Y \quad (1)$$

And

$$F = \left(\frac{1}{D^2}\right) Pixels/grid\ area \quad (2)$$

Now, exploiting the coverage information we got from the division of intensities into classes, the location at which the pixel is placed i.e. Dx and Dy values in pixel coordinate space and the factor F which states the number of subpixels into which we are dividing the pixel gives us the subpixel coordinates.

$$\delta_x = \left(\frac{D_x}{D}\right) \times F \times (\%\ coverage) \quad (3)$$

$$\delta_y = \left(\frac{D_y}{D}\right) \times F \times (\%\ coverage) \quad (4)$$

Also, subpixel accurate edge coordinates are:

$$Dx' = Dx + \delta_x \quad (5)$$

$$Dy' = Dy + \delta_y \quad (6)$$

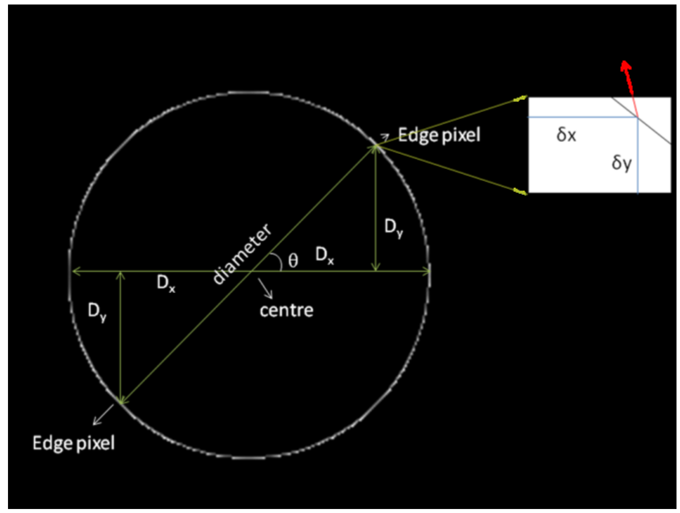

Fig.3 *Representation of parameters in pixel coordinate space.*

VII. DIMENSION CALCULATIONS

From the subpixel coordinates obtained and repeating it for the diametrically opposite pixel, we can get the diameter measurement by simply using the formula mentioned.

$$Diameter\ (mm) = Diameter(pixels) \times \left(\frac{length}{pixel}\right) \quad (7)$$

From these calculations error can be calculated as the difference between the measured and exact value of the diameter.

Error=actual diameter-measured diameter (8)

Now, subpixel order or subpixel factor will be calculated as the function of error and length per pixel. Subpixel order is the factor up to which we can increase resolution or minimize the least count of measurement when measuring in terms of pixel.

Hence, order of subpixel resolution is:

$$Subpixel\ order = \left(\frac{length/pixel}{error}\right) \quad (12)$$

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VIII. EXPERIMENTS AND RESULTS

Initially, to start with the experiments camera calibration[2] was done to eliminate all the non linearity in machine vision measurements. The experiments were carried out with various circular objects with proper back lighting arrangements (stable lights with constant illumination). Smart camera with resolution 640 X 480 was used. All the cases derived above is for $0<\theta<90^{\circ}$.The same cases are applied for rest of the quadrants with proper choice of θ and reference axes. Calculations were made for all the edge pixels according the cases mentioned. Empirically, it was found that an subpixel order up to 20 can be easily achieved with repeatability of almost 94% with all the different objects being tested.

Acknowledgment

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