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Object Speed Estimation in Frequency Domain of Single Taken Image

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ABSTRACT

In this paper we propose a novel approach for speed estimation of Spherical Object in frequency domain. Motion blur is the result when the camera shutter remains open for an extended period of time and a relative motion between camera and object occurs. Speed estimation is performed by camera parameters, imaging geometry and blur parameters.

KEYWORDS: Object Speed, Frequency Domain, Single Taken Image

1. INTRODUCTION

Because of advances in the development of football, baseball exercise, and electronic devices, people are becoming more interested in knowing the speed of flying objects, the pitching speed of sports players. Currently, Method of speed estimation is categorized into two classes. First, Active Method: The most popular methods include using RADAR and LIDAR devices to detect the speed of object. A LIDAR device times how long it takes a light pulse to travel from the LIDAR gun to the object and back. Based on this information, LIDAR can quickly find the distance between the gun and the object. By making several measurements and comparing the distance the object is traveled between measurements. Second, Passive Method [1,2,3]: In these Method, speed information, is extracted from a sequence of real-time images, taken from passive camera. . Motion blur is the result when the camera shutter remains open for an extended period of time and a relative motion between camera and object occurs.

Image degradation caused by motion blur can be classified as spatially invariant or spatially variant distortions based on the formation of the imaging process. Spatially invariant distortion corresponds to the cases that the image degradation model does not depend on the position in the image. The motion blur we have to deal with appears in the image containing a fast moving object and recorded by a static camera. The corresponding PSF is a function of position in the image, and thus it is classified as spatially variant distortion.

Blur parameter identification methods can be classified into two type, spatial domain and frequency domain [6,7]. In the spatial domain, first, the SOBEL edge detector is applied to the image, then a iterative method is used to extracted motion length. Since for linear motion of a scene the blurring effect mainly occurs in the motion direction, the intensity of high frequency components a long this direction is decreased.

In the frequency domain, 2D" Fourier spectrum is taken from image, that the blurring is occurred. There is direct relation between speed of spherical object and blur parameter.

In the other word when the speed of object is increased, motion length is increased too. In this paper we propose a novel approach for object speed estimation for extracting blur parameter in the frequency domain, based on a single image. Due to the relative motion between camera and the moving object and finite exposure time motion blur will appear on the image. As shown in Fig.1, moving object generates blurring in taken image.

Fig.1. Moving object in static background

For any fixed shutter speed, the moving speed of object is proportional with amount of blur caused by the imaging process. Thus, if the parameters of the motion blur (the length and orientation of the motion blur) can be

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identified, it is possible to recover the speed of the moving object according to the imaging geometry. Our proposed method improved accuracy of speed estimation and measurement of motion blur parameters other than existence methods such as Huei-Yung Lin& Chia-Hong Chang method[8,9].

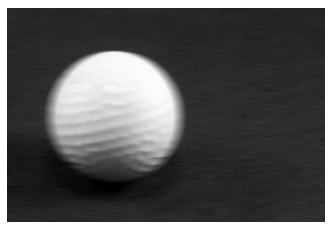
1. Mathematical Model of Linear Motion Blurring and Its Attributes

we consider the Spatially Invariant case of uniform linear motion along horizontal direction, then PSF h (x , y) is given by:

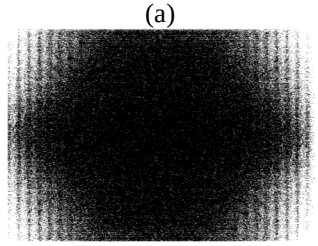
$$h(x,y)=\begin{cases}1/L & if \quad \sqrt{x^2+y^2}\le L/2 \,\&\, \frac{x}{y}=-tg\phi \\ 0 & otherwise\end{cases} \qquad (1)$$

As seen in equation (1), motion blur depends on two parameters: "*L*" Motion length and "ϕ" Motion direction.

In frequency domain of observed image, the dominant parallel lines occurred**.** Fig.3 shows two images with different speed of spherical objects and their Fourier spectrum that it is affected by motion & radial blur. The dominant parallel dark lines are obvious in the Fourier spectrum of this image in the fig.2-b.



(a)



(b)

Fig.2.(a),(b)Blurred image and its Fourier transform.

2. Motion Blur Parameters Estimation

For using a motion blurred image for object speed estimation, the direction and extent of motion blur have to be identified. It is clear that the motion direction of a moving object (appeared in the image) is the same as the direction of motion blur. The blur extent of a moving object can be obtained from Fourier transform.

2.1 Motion Direction Estimation

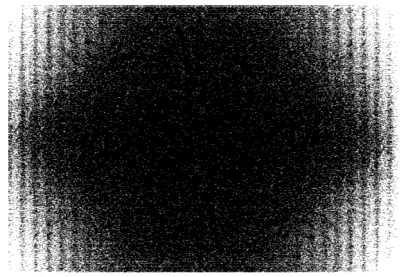
We consider the case that the moving object travels along a direction perpendicular to the optical axis of the camera. Then the angle of motion direction will be zero($\phi=0$).So that the direction of object motion is reduced to a one-dimensional case.

2.2 Motion Length Estimation

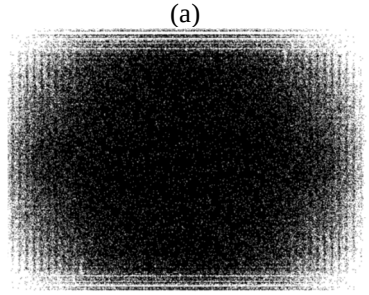
To estimate the motion length of the spherical object, the length of the motion blur, The frequency response of degradation function in the horizontal direction is given by equation (4):

$$H(u)=\frac{\sin(\frac{Lu\pi}{N})}{L\sin(\frac{u\pi}{N})} \qquad (2)$$

In proposed method *L* is found without a need to solve *H(u) = 0* [6]. By looking carefully at several Fourier spectrums of motion blurred images show that increasing the length of motion blur creates more dark line with shorter distance between these lines. Fig.3 illustrates this fact.



(a)



(b)

Fig.3. (a),(b)blurred images with $L = 30, d = 24$, $L = 50, d = 14.5$ and their Fourier transforms.

Motion length, "L", is proportional with reverse of line distance, "d" .

In this stage, the line distance is calculated, that is appeared in blurred images. However we cant calculate motion length by finding distance between lines in the Fourier spectrum, since motion length(L) and line distance (d) is related together are not equal, because of there is mathematical relation between line distance (d) and motion length(L). Several images by specific motion length are generated, then line distance is measured. For each of images the $L\&d$ is plotted in a dL space. Then, by using a curve fitting algorithm, with a polynomial of degree n, a curve is fitted between L and d.

$$L(d) = p_1 d^5 + p_2 d^4 + p_3 d^3 + p_4 d^2 + p_5 d^1 + p_6 \quad (3)$$

The constant values $P\ i$ are given in table(1). It is important to note that equation(3) is image independent because the line distance on the frequency response depend only on zero points on the frequency response of degradation function that is caused by convolving the PSF with the input image.

Table1. Constant value of Eq.3

P1	P2	P3
$-3.3425*10^{-7}$	$9.531*10^{-5}$	-0.0110
P4	P5	P6
0.5108	-11.8568	145.068

3. Speed Estimation of Spherical Object

The proposed method for speed measurements is based on a pinhole camera model. In this paper, Huei-Yung Lin and Chia-Hong Chang formulation is used for speed estimation with blur content that are extracted in previous section[3]. In this method, camera position is showed in fig.4.

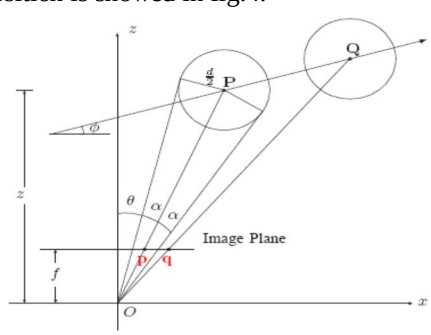


Fig.4. camera position.

As shown in Fig.(4), suppose the center of a spherical object with diameter d is located at P = (x, y, z) in the camera coordinate system and the corresponding image point is p = (ˆx, ˆy). The proposed formulation for speed estimation, ”*v*” is:

$$v = Ld / WT \qquad (4)$$

That L(K),d ,W,T are blur extent, diameter of the object measured physically, diameter of the object observed in the image and shutter speed, respectively.

4. EXPERIMENTAL RESULT

In the first experiment, an image of static softball in front of background is presented. By MATLAB, synthetic motion & radial blurred image with {15,20,25,30,35,40}pixels of horizontal blur length is created. Then, with aided purposed algorithm in the frequency domain, blur extent is calculated, that are as flow,{15,20,29,36,41}. The output data is showed 3% error in the blur lengths, equally ±1 pixel error. The proposed speed estimation algorithm for spherical objects have been tested on real images from outdoor scenes with softball pitching. The camera was placed approximately perpendicular to the motion direction of the softball. Eq(4) is used for speed measurements with camera shutter speed T = 1/320 sec, and softball diameter d = 97.45 mm. In second experiment, For the images shown in Figs. 2-b 2, the blur extent and the size of the softball are identified as 26 and 72 pixels, respectively. Thus, the speed is found to be 40.54 km/hr.

To find the relative error of our method compared to a video-based approach, a video camera was used to record an image sequence of each experiment. The speed is calculated by the distance traveled between two fixed locations divided by the time difference. The results are shown in Table I for both cases (V1 and V2). Most of the results from our method(S1 and S2) and the video-based approach have less than 4%

Table2. Softball speed measurements (km/hr) of motion blurred images(S1,S2) and video approach(V1, V2).

No	1	2	3	4	5	6	7	8
S1	38.9	31.7	35.1	31.5	38.4	34.4	39.5	43.2
V1	40.9	37.2	38.9	34.2	40.4	38.2	41	45.3
S2	37.2	35.4	32.7	47.4	40.3	48.1	46.8	44.7
V2	37.1	39.1	36.5	48.1	35.4	44.3	51.5	46.6

Difference for the first set of experiments (where the ball was moving parallel to the image plane), and less than 11% difference for the second set of experiments (where the ball was moving about 20 degrees off the image plane). Some results with large error for the second case could be caused by incorrect angle _ for the motion direction.

5. CONCLUSION

In this paper, we have presented speed measurement method of spherical objects using a single image that it taken in front of a still background. Blur parameters of the motion blurred image are estimated in the Fourier transform space and then used to calculate the speed of the object according to a pinhole camera model. Since this approach is an image-based method, it can be implemented with low cost digital cameras.

6.Acknowledgements

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