ESTIMATION OF DISTANCE FOR DETECTION OF OBSTACLE USING COMPLEX LOG MAPPING

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Abstract

In this paper, a new method is proposed to measure the distance from the camera to an object's surface with arbitrary digital images. The method uses two images which are taken at two camera positions while moving the camera along its optical axis. The distance between the two camera positions is assumed to be known. The distance from the camera to the object is computed by calculating the ratio between the sizes of the object projected on the two images. To calculate the ratio, Complex Log Mapping is applied according to the fact that the two images have concentric circles features. In the complex log mapping, the original images are mapped from the orthogonal coordinate system to the polar coordinate system.

Keywords: Complex log mapping, Image processing steps, Correlation schemes.

1. Introduction

Measuring the distance between the object and the camera surface is widely applicable in many fields. Manual distance measurement is not possible in the fields of satellite communication, intelligent transport systems, qualitative and quantitative analysis etc. so, it is now interested in measuring the distance of the object from the camera surface. The principle step in the project includes capturing the image of the target object at two camera positions by moving the camera along the optical axis. The distance between the two camera positions is assumed to be known. The distance from the camera to the object is computed by calculating the ratio between the sizes of the object projected on the two images. To calculate the ratio, Complex-Log Mapping (CLM) is applied[2][3].

The main objective is to measure the distance of an object with arbitrary texture surface where the manual estimation is not possible. The kind of measurement is used in

- target location
- space variant computer vision
- avoiding vehicle collision

Many methods are available for measuring the distance between the camera and the object surface. They are:

1. Stereo vision method
2. Shape from focusing method
3. Shape from texture method

Of them stereo vision is most popular one because the environment has no influence on the measurement, the only work that is supposed to do is searching of corresponding points between the left and right images. However, this method cannot be applied to measuring the distance of a texture surface. On the other hand, other two methods can be applied for measuring the distance of the texture surface. Of them shape from focusing method is applied to any texture surface[3], but a strict measurement condition is necessary. Shape from texture method can be used when the texture feature is known before hand and the strict measurement condition is not necessary. So it is proposed a new method for the distance from the camera to the surface of an object and it is available for arbitrary texture surface and strict measurement condition is not necessary.

2. Brief Review of Complex Log Mapping

Image acquisition is the first process that could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves pre-processing, such as scaling.

Image enhancement is among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement technique is to bring out detail that is obscured, or simply to highlight certain features of interest in an image.

A familiar example of image enhancement is when the contrast of an image is increased because "it looks better". It is important to keep in mind that enhancement is a very subjective area of image processing as shown in figure 1 in the detailed block diagram.

Image restoration is an area deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration technique tend to based on mathematical or probabilistic models of image degradation. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a good enhancement result.

Compression deals with the technique for reducing the storage required to save an image, or the bandwidth required to transmit it. Segmentation procedures partition an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing.

A rugged segmentation procedure brings the process a long way toward successful solution of image problems that require objects to be identified individually [5]. On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. The more accurate the segmentation, the more likely recognition is to succeed.

Representation and description almost always follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of region or all the points in the region itself. In either case, converting the data to a form suitable for computer processing is necessary. The first decision that must be made is whether the data should be represented as a boundary or complete region.

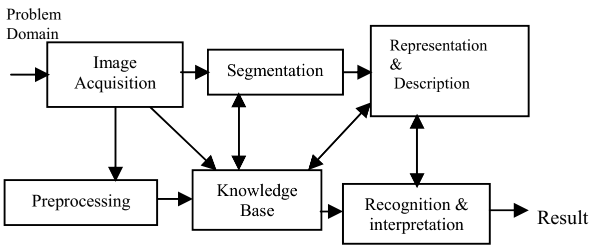

Figure 1. Digital Image Processing Fundamentals description also called feature selection

deals with extracting attributes that results in some quantitative information of interest or are basic for differentiating one class of subjects from another.

This method is to measure the distance between the cameras to an object's surface with arbitrary texture pattern. The method uses two images which are taken at two camera positions, while moving the camera along its optical axis. The distance between the two camera positions is assumed to be known.

By the CLM, the original images are mapped from the orthogonal coordinate system, i.e., the *x-y* plane, to the polar coordinate system, i.e., the *k-l* plane.

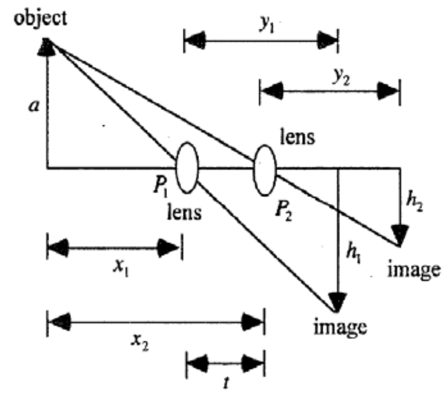

Figure 2. Principle of distance measurement

In this figure 2, a is the size of the object which is considered in this project, x_i is the distance between the object and the camera, y_i is the distance between the camera and the projected plane(image), h_i is the size of the object projected on the image, namely the size of the image component and f is the focal length of the camera.

$$\frac{1}{x_i} + \frac{1}{y_i} = \frac{1}{f} \quad (1)$$

$$h_i . x_i = a . y_i \;\; (i = 1,2) \quad (2)$$

Are the lens formulas, and if the camera is moved by a known distance t form P_1 to P_2, along the optical axis, then

$$x_1 - kx_2 - f(1-k) = 0 \quad (3)$$

$$t = |x_1 - x_2| \quad (4)$$

where k is the ratio of h_1 to h_2. When k is obtained, x_1 and x_2 are calculated from the equations,

$$x_1 = f - \frac{k}{1-k} . t \quad (5)$$

$$x_2 = x_1 - t \quad (6)$$

In this paper the distance measurement between the camera and the surface is substituted by calculating the ratio between component sizes of each image. From now, it is the ratio between two images; it is simple to obtain the ratio between the images and measuring the size of corresponding part of that image. For example, length and area, but as the object surface has random texture, it is impossible to get the value directly.

Two images obtained by a camera which is moved along the optical axis have some properties. One of them is that one image can be obtained by reducing or magnifying the other radially. The center of changing size is the intersection point of the optical axis and the image plane, namely the center of visual field.

Now, consider that a pixel (x_i , y_i) on original image is mapped at the pixel (m_i, n_i) on mapped image by CLM as (c_x,c_y) denotes the center of visual field, let is denoted by $F_0(x_i, y_i)$. The gray scale at (m_i, n_i) is denoted by $Mo(m_i, n_i)$ to be the mapping origin and r be the mapping radius. The gray scale at (x_j, y_j) The relation between x - *y* plane and m-n plane is given in the equation,

$$M_o(m_i, n_i) = \frac{z}{r} F_0(x_i, y_i) \quad \textbf{(7)}$$

where $z = \sqrt{x_i^2 + y_i^2}$,

$$\theta = \tan^{-1}\frac{y_i}{x_i},$$

$$m_i = N \cdot \frac{\theta}{2\pi}$$

$$n_i = N.\log_r z$$

N is the size of the mapped image, m_i and n_i are calculated in terms of distance, z, and direction, θ, from the mapping origin, (c_x,c_y), to the mapping pixel, (x_i, y_i), on original image.

The complex log mapped image geometry was first motivated by its resemblance with the structure of the retina of some biological vision systems and by its data compression qualities. When compared to the usual Cartesian images, the log-polar images allow faster sampling rates on artificial vision systems without reducing the size of the field of view and the resolution on the central part of the retina (fovea). In the last years, however, it has been noticed that the log-polar geometry also provides important algorithmic benefits. For instance,[4][5] it is shown that the use of log-polar images increases the size range of objects that can be tracked using a simple translation model. It is expected that increasing the "order" of the transformation towards the planar model, these advantages can still be observed.

The log-polar transformation[1] is a conformal mapping from the points on the cartesian plane (x, y) to points in the log-polar plane, as shown in figure 3.

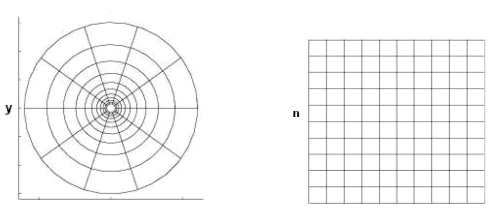

Figure 3. Complex Log Mapping with Cartesian plane and Log polar plane

The mapping is described by:

$$m = \log\sqrt{(x^2+y^2)}$$

$$n = \tan^{-1}(y_i/x_i)$$

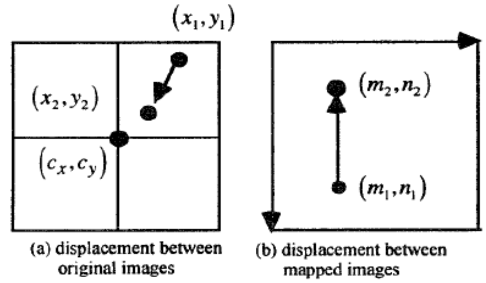

Figure 4. Displacement between corresponding points

Now, consider that two images are converted by same CLM whose mapping origin is the center of visual field. Here, suppose that pixel *(x_1,y_1)* on one image is correspondent with pixel (x_2,y_2) on the other image. And mapped pixels of (x_1,y_1,) and *(x_2,y_2)* are located at ***(m_1,n_1)*** and *(m_2,n_2)* on mapped image, respectively as shown in figure 4. The displacement between two original images is shown as the arrow. There is no rotational displacement between two pixels on original images. That is, the distance from the center of visual field, (c_x , c_y) to (x_1,y_1)is different from that to (x_2, y_2),but the direction is the same. The displacement between two pixels on mapped images is shown in figure 4. The two component values at the axis m are equal and those at the axis n are not.

Consider that each original image is converted by a different CLM. Two mapping origin are at the same position, (c_x,c_y), but mapping radius r1and r2 are different. Where, z1 and *z2* are distances from (c_x,c_y) to (x_1 , y_1) and (x_2,y_2) respectively, and the ratio between zI and z_2 is the ratio between two images. If $z_1 /r_1 = z_2/r_2$, n_I is equal to $n_2$because of the principle of CLM. If $z_1/r_1=z_2/r_2$, $z_2/z_1=r_2/r_1$, that is, when the ratio between two mapping radii is equal to the ratio between two images, two mapped images become the same. This relation means that the visual field within *r,* on one original image is equal to that within r_2 on the other image. This shows that corresponding area between two original images can be found by using CLM. The corresponding area becomes a circle area whose origin is the center of visual field as shown in Fig. *5***.** And the ratio between two images is equal to the ratio between the radiuses of each of the two circles. Using this property, it is proposed a new method to calculate the distance between two images.

3. Proposed Work

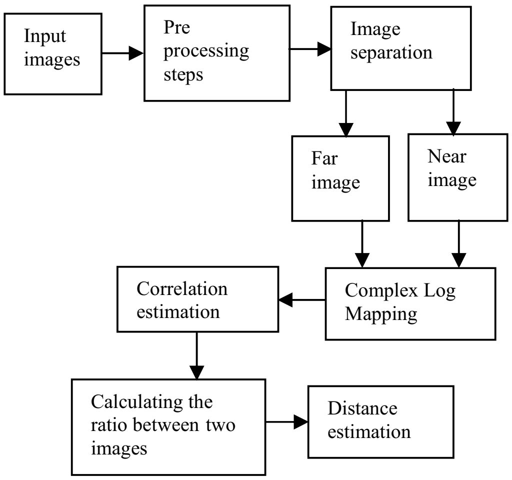

Figure 5. Detailed Block diagram

Two images of the target object are captured. The method uses two images which are taken at two camera positions, while moving the camera along the optical axis. Let the positions be P_1, P_2 respectively. The distance between two camera positions is assumed to be known, as detailed in the block diagram as shown in figure 5.

The preprocessing steps are image processing is acquired to remove the noises and blurring in images. Digital images are prone to a variety of types of noise. Noise is the result of errors in the image acquisition process that result in pixel values that do not reflect true intensities of the real scene. If the image is acquired directly in a digital format, the mechanism for gathering the data can introduce data.

The blurring or degradation of an image can be caused by many factors.

- Movement during the image captures process, by the camera or when long exposure time is used by the subjects.
- Out of focus optics, use of a wide-angle lens, atmospheric turbulence, or short exposure times, which reduces the number of the photons captured.
- Scattered light distortion in confocal microscopy.

Complex logarithm function is an inverse of the complex exponential function, just as the natural logarithm $\ln x$ is the inverse of the real exponential function e^x. So a logarithm of z is a complex number w such that $e^w = z$. For each nonzero complex number z, the principal value $\text{Log}\, z$ is the logarithm whose imaginary part lies in the interval $(-\pi,\pi]$. The expression $\text{Log}\, 0$ is left undefined since there is no complex number w satisfying $e^w = 0$

Complex log vision reduces the amount of data to be stored and processed, simplifying several vision algorithms. The log polar representation of an image has the interesting properties. As an example of particular computational simplifications, rotations around the image centre are converted to simple translations along the angular coordinates, and homothetic with respect to the centre of the image plane become translations along the radial coordinates. The complex log conversion, performed at the present system consists of calculating the transformation to log polar coordinates, for every pixel coming from the camera.

The chosen CLM has two stages: the first calculates the polar co-ordinates (radius and angle) of the Cartesian co-ordinates (x, y). The second stage calculates the logarithm of the radius giving the final log- polar co ordinates.

The correlation is one of the most common and most useful statistics. A correlation is a single number that describes the degree of relationship between two variables. In image processing correlation gives the degree of relationship between two images.

In order to find the distance between two images, the image which is taken at nearer position that is the reference image, is mapped whose mapping radius is r_1.

Then the adjusting image is mapped, with the radius r_2, $r_2 < r_1$. Then the correlation between two mapped images is obtained. Then the adjusting image is mapped by varying its radius. And the corresponding correlation is to be found. Radius of the adjusting image for which the correlation is maximum is $r_{max.}$ The ratio r_{max}/r_1 gives the ratio between two images

According to the property of CLM, ratio between two images is obtained by extracting two circles from each of the two images. The ratio between two images us equal to the ratio between the radiuses of each of the two circles. This process of calculating the ratio is carried out by fixing the radius of the circle on one image which is the reference image, while changing the radius of the circle on the another image. One of the two images, which is the reference image (most probably the image which is taken at nearer position) is converted by CLM. In this mapping, let the mapping radius be r_1, and the origin is the centre of visual field, (c_x, c_y). Image M1 (m_x, m_y) is obtained by above mentioned mapping process. The other image is the adjusting image which is taken, where the distance between the object surface and the lens of the camera is larger when compared to that of reference image, is converted by CLM. The mapping origin is same as that of reference images and the radius r_2, which is obtained by shorting r_1. The complex log mapped image, M2(m_x, n_y) is obtained[6]. The correlation between the mapped images $M1(m_x,n_y)$ is calculated using ,

$$\frac{\sum_{m_i=1}^{N}\sum_{n_i=1}^{N}\left(M_1(m_x-n_y)-\mu_1\right)\left(M_2(m_x,n_y)-\mu_2\right)}{\sqrt{\sum_{m_i=1}^{N}\sum_{n_i=1}^{N}\left(M_1(m_x,n_y)-\mu_1\right)^2\sum_{m_i=1}^{N}\sum_{n_i=1}^{N}\left(M_2(m_x,n_y)-\mu_2\right)^2}}=\frac{\sigma_{12}^2}{\sqrt{\sigma_1^2\sigma_2^2}}$$

$M_i(m_x,n_y)$ - mapped images with origin c(x,y)
C(x,y) - centre of visual field
μ_i - average value of each mapped image,
σ_i is the variance value of each mapped image,
σ_{12}^2 is the co-variance value between each mapped image (i = 1, 2). The adjusting image is taken by moving a camera from the position where the reference image is taken. (c_x, c_y) does not shift if the camera is moved perfectly along its optical axis, but it is impossible to move the camera along its optical axis perfectly. In addition,(c_x,c_y) shifts by the sampling error. Many $M2(m_x, n_y)$ are got by many CLMS whose mapping origins are all pixels around(c_x,c_y) and mapping radius is kept constants as r_2.correlations between all $M1(m_x, n_y)$ and $M2(m_x, n_y)$ are calculated. Among them, the maximum value becomes the correlation between $M1(m_x, n_y)$ and $M2(m_x ,n_y)$ mapped by r_2.

In this paper, reference image is taken at nearer position from the surface than the adjusting image. If the reference image is taken at farthest position from the surface, the visual field will be narrower than that of the image which is taken at the nearest position. The lack of image components causes the error when the correlation between the two mapped images is calculated. So, reference image is taken at nearer position from the surface so that all of image component on reference image is included in those on adjusting image.

4. Results and discussion

To evaluate the system, a small test method is developed and the simulation is designed which is close to the application applied in real condition. These results have been obtained by passing the same tests on different distances and measurements are obtained, as the graph shown in Figure 5 gives a theoretical distance value and practical measured value. A detailed result graph is shown in figures 6 & 7 below for an image captured in both open and closed environment.

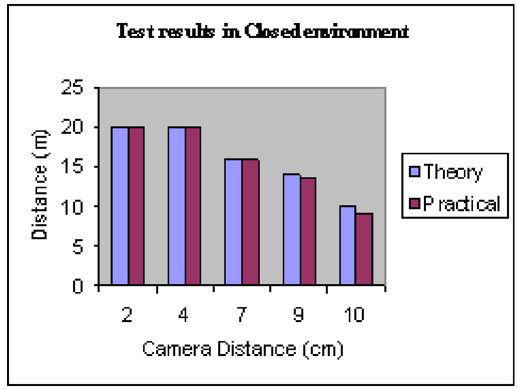

Figure 6. Test results in closed environment

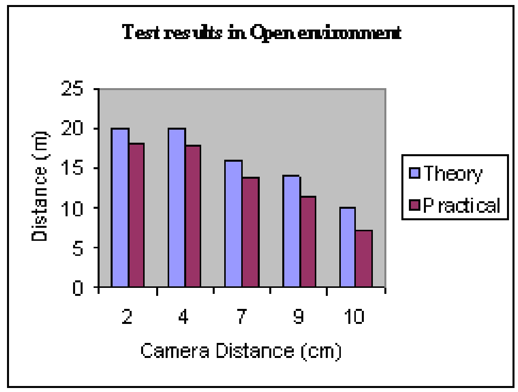

Figure 7. Test results in Open environment

The results show that our system is quite useful when the image captured in closed environment. For smaller range it is higher, for larger range it is lower.

Dynamic obstacle detection is still need to be improved. In fact this system approximates properly the distance to the obstacle but it still hard to localize it precisely.

5. Conclusion and Future Work

In this paper, the novel method to capture image and pre-process the images by using CLM are proposes. The proposed method requires only a few numbers of calculations and table-look up operations. Hence, the proposed method enables faster processing in closed than open environment. The obtained images have similar quality and need some neighborhood method to be used.

In this part, the time cost is high because sequential method is used when calculating the distance between two images. Therefore, our future work will firstly involve in reducing the processing time. Also, another method has to develop which can measure the object with slant surface.

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BIOGRAPHY

J.Venu Gopala Krishnan graduated in Madras University, Chennai at 1992 in Electronics & Communication discipline and started his teaching career. Then he pursue his Master’s degree in Optical Engineering in CEG, Anna University, Chennai and awarded at 2001. He is doing his research work in the field of Image processing. Now he is a Professor & Head in the department of Electronics & Communication Engineering of Jeppiaar Engineering College, Chennai. He presented 18 papers in National and International Conferences. He published 2 papers in International Journals.