# ESTIMATION OF DISTANCE TO TEXTURE SURFACE 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 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. 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, Texture surface, 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 interested now 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.

The main objective is to measure the distance of an object with arbitrary texture surface where the manual estimation is not possible[2][3]. 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

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 which is shown below in figure 1.

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[5].

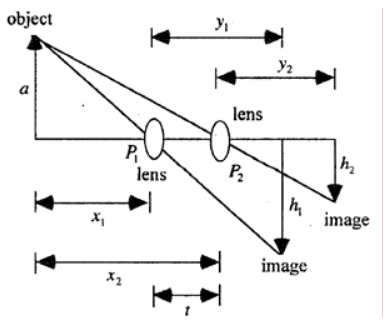


**Figure 1. Principle of Distance Measurement**

In this figure 1, $a$ 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.

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

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

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, now find the ratio between two images. It is simple to obtain the ratio between the images and measure the size of corresponding 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 radically. 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 ($m_i$, $n_i$)s denoted by $Mo(m_i, n_i)$. it be the mapping origin, and ,let r be the mapping radius. The gray scale at ($x_j$, $v_j$) The relation between $x$ - $y$ plane and m-n plane is given in the equation,

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

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, 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 expects that increasing the "order" of the transformation towards the planar model, these advantages can still be observed.

The log-polar transformation is a conformal mapping from the points on the Cartesian plane (x, y) to points in the log-polar plane as shown in fig.2,

The mapping is described by:

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

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

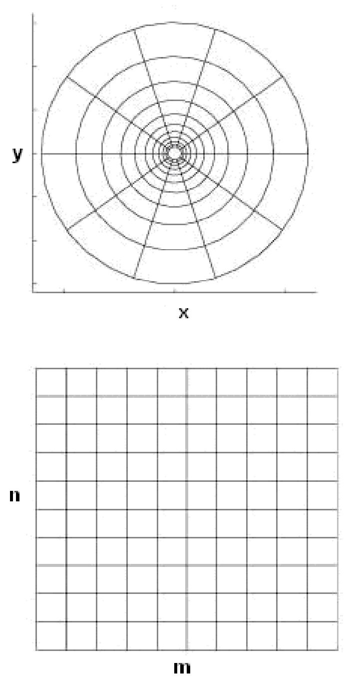


**Figure 2. Complex Log Mapping with Cartesian plane and Log polar plane**

The unit circle in the $z$-plane is mapped into a segment of the imaginary axis in the $w$-plane, running from $-\pi i$ to $\pi i$. Notice that the length of the resulting straight line segment equals the circumference of the original circle.

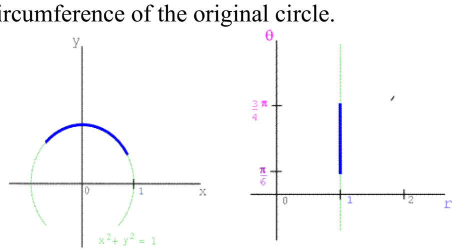

**Figure 3. Circle Mapped into Line Segment**

The interior of the unit circle is mapped into the left-hand portion of the strip; that is, into the region where $\mathrm{Re}(w) < 0$. More precisely, each circle centered on the origin and of radius $r < 1$, $|z| = r$, is mapped into the straight line segment $\mathrm{Re}(w) = \ln(|z|)$. Each of these line segments is longer than the circle whose image it is, and the smaller the circle, the more it gets stretched out as shown in fig. 3.

The exterior of the unit circle is mapped into the right-hand portion of the strip; each circle $|z| = r > 1$ is straightened out and compressed to fit on the line segment $\mathrm{Re}(w) = \ln(|z|)$ as shown in fig. 4.

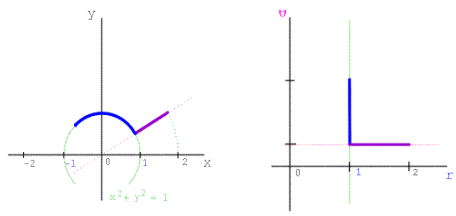

**Figure 4. Exterior right hand portion**

The positive real axis in the $z$-plane is mapped into the entire real axis in the $w$-plane. More precisely, if $z_0$ is real and $z_0 > 0$, its image $w_0$ is given by $w_0 = \ln(z_0)$. The negative real axis is mapped into the straight line $\mathrm{Im}(w) = \pi$, with one notable difference – its direction is reversed. That is to say, the negative real axis, which runs from right to left in the $z$-plane, is mapped into a straight line running from left to right in the $w$-plane as shown in fig. 5.

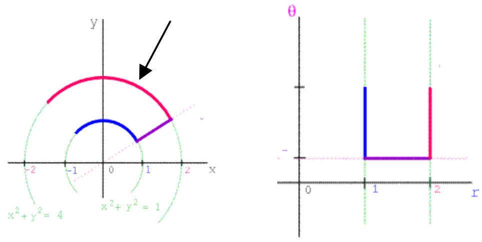

**Figure 5. Conformal mapping of the real axis**

All the rays originating at $z = 0$ are mapped into parallel horizontal lines in the $w$-plane. Rays that are "close" to the positive real axis lie close together in the $w$-plane, and rays that are '"close" to the negative real axis are farther apart, because the image of each ray $\arg(z) = \theta$ is the straight line $\mathrm{Im}(w) = \theta$ as shown in fig. 6.

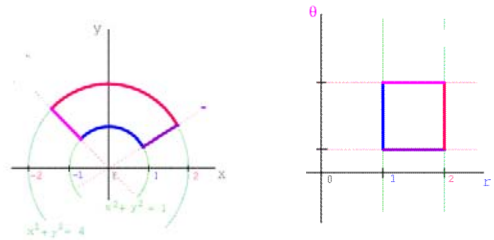

**Figure 6. Conformal Mapping of the Rays**

Since the mapping $w = \log(z)$ transforms circles into vertical straight line segments, it is useful in engineering applications involving an annulus, or doughnut-shaped region; the image of the annulus is a rectangle of height $2\pi$, whose width depends on the thickness of the annulus. By the same token, the inverse mapping $z = e^w$ transforms a rectangle into an annulus.

Log($z$) also serves as a particularly simple illustration of the principle that conformal maps preserve angles. All the circles and radial lines discussed above are mutually perpendicular, as are the vertical and horizontal lines into which they are transformed.

Finally, the complete map of the corkscrew Riemann surface on which log($z$) is holomorphic into the complex plane is easily visualized – each "sheet" of that surface is mapped into an infinitely wide strip of height $2\pi$, and those strips cover the entire complex plane.

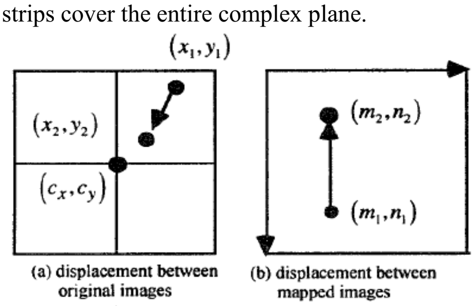


**Figure 7. Displacement Between Corresponding Points**

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 fig. 7. 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 .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 $r_1$ and $r_2$ are different. Where, $z_1$ and $z_2$ are distances from $(c_x,c_y)$ to $(x_1, y_1)$ and $(x_2, y_2)$ respectively and the ratio between $z_1$ and $z_2$ is the ratio between two images. If $z_1/r_1 = z_2/r_2$, $n_l$ 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[5]. 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 radius 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

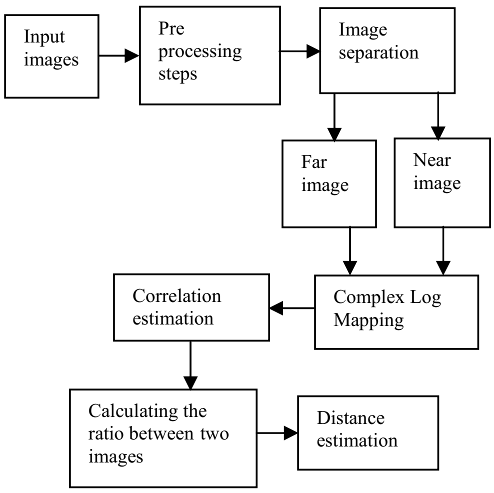


**Figure 8. Detailed Block diagram**

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 shown in fig. 8.

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 capture process, by the camera or when long exposure time are 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 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.

## 4. RESULTS AND DISCUSSION

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, which 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. The correlation between the mapped images M1($m_x$,$n_y$) is calculated[6] using,

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

$M_i$ ($m_x$,$n_y$) - mapped images with origin c(x,y)
C(x,y) - centre of visual field
$\mu_i$ - average value of each mapped image
$\sigma_i$ is the variance value of each mapped image
$\sigma_{12}^2$ 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. Table 1 shows the results obtained for the various texture surfaces distance from the camera positions.

**Table 1 – Results obtained for the various texture surfaces:**

| Real distance (mm) | Grass lawn (mm) | Reptile skin (mm) | Ceramic coated brick wall (mm) |
|---|---|---|---|
| 500.0 | 491.4 | 494.2 | 499.6 |
| 600.0 | 606.6 | 589.9 | 601.3 |
| 700.0 | 710.8 | 684.1 | 702.2 |

## 5. CONCLUSION AND FUTURE WORK

In this paper, a new method is proposed for measuring the distance to texture surface by calculating the ratio between two images taken by a monocular camera moved on its optical axis.

To obtain the distance, Complex-Log Mapping is used according to the face that the two images have concentric circle features. From the experimental results, the validity of this method was verified.

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 new 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 pursued 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 the Professor and Head in the department of Electronics & Communication Engineering of Jeppiaar Engineering College, Chennai. He has presented 18 papers in National and International Conferences. He has published 2 papers in International Journals.