# High Resolution Imaging by Using Phase Modulated wavelets

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**Abstract:** It is proposed to achieve high resolution within image from low resolution images. This method has three steps: Registration, Interpolation and Reconstruction. In Registration the specimen under investigation is photographed from different angles and from different positions using holographic techniques and these low resolution images are superimposed in a particular reference plane. In Interpolation, the photograph is divided into several finite elements. As the number of element is very large, each element is more or less of point size called Pixel. The finite elements are scanned by laser beam of given frequency and amplitude. The resulting beam from each node has a phase variation dependant on the pixel density. This phase dependant wavelets are digitalized and magnified. The final process is recombination of the amplified digital signals. The final image obtained has high resolving power, super clarity, distortion less magnification and three dimensional views.

**Key Words:** Shape function, hologram, and interpolation, Phase modulated wavelet, high resolution, Contrast ratio, three dimensional views.

## INTRODUCTION

The requisites of an ideal image are High resolution, Super clarity, Distortion less magnification and three dimensional views. These features of an image are essential for the precise analysis of a specimen. Such images have wide applications in military, medical field and consumer electronics.

High resolution of images can be achieved using digital signal approach. Resolution implies that different parts of a sample are separately seen. The resolving of an optical device is its power to see two separate objects as separate. When a point object is viewed by an optical device, owing to diffraction effects it appears to have a central bright spot surrounded by concentric subsidiary minima and maxima. Owing to this diffraction effect the image will be blurred. If we observe two nearby point objects they may not be seen as separate objects but seen as single object. Then the objects are not being resolved. According to Raleigh's criterian of resolution two nearby point objects are just being resolved if the central spot of one image lies on outside the first subsidiary minimum of the other objects. Using this principle it is obvious that the resolving power of optical device is proportional to (a/⊚, a being the aperture of the device, being the wavelength of the light used. So resolving power can be increased either by increasing the aperture of the device or by decreasing the wave length of light used.

There are different methods to get high resolution images from low resolution images using super resolution algorithms. One such method is interpolation by using frequency wavelet method. We propose another method of getting high resolution images that is by using Phase Modulated wavelets.

It is quite logical to note that the image obtained by merely sampling and interpolating a low resolution image will not have high resolution than original. The resolving power can be increased either by 1. Adding high frequency information based on the knowledge of the specific image model or 2. By removing the ambiguity in held in the image. The latter can be effected by the additional information obtained from other images of the same scene. We adopt this method.

For interpolation we make use of phase conclude wavelets by a laser beam of fixed frequency and fixed amplitude. Then we repeat our interpolation process by using set of selected frequencies. Another aspect for which we are interested is the clarity of the image. When we observe a specimen by optical image the image is blurred due to diffraction effects. The clarity of a particular part of the image is decided by contrast factor or modulation factor defined as C=$\frac{Imax-Imin}{Imax+Imin}$, I MAX is the maximum intensity and I min is the minimum intensity. As the frequency of the observing signal increases the contrast factor and accordingly the visibility factor increases.

Another requirement of image is distortion less magnification. If we use a narrow width of frequencies, magnification is same for different parts of the image and so we get distortion less magnification. Hence the image is a true replica of the specimen.

When the full phase variation on scanning the specimen is recorded a 3-D view is obtained. Thus we aim to achieve a high resolution image of super clarity with distortion less magnification and 3-D appearance.

Holography- Record of phase variation when an object is irradiated by light.

When we photograph an object using traditional means by light field we get a point by point record of square of the amplitude. The light reflecting of the specimen carries with it the information of irradiants and it does not describe the phase of the wave emanated from the object. If both the amplitude and phase of the original wave can be reconstructed, the resulting light field would form an image perfectly three dimensional exactly as if the object were before you. One such method is used in phase contrast microscope and another such device is holographic technique. The principle of holography is Dennis Gaber. He photographically recorded an interference pattern generated by interaction of scattered monochromatic light beam from an object and coherent reference beam. The record of this resulting pattern is called hologram. This is the first step of the holographic technique. The second step is the reconstruction of the optical field or image formed by the diffraction of the coherent beam by the hologram. The clarity of the photograph is decided by the contrast factor.

When we photograph a point object, because of diffraction it is imaged as a smear of light described by a point spread function S(x,y). Under incoherent illumination these elementary flux density pattern overlap and add linearly to create a final image. An object is a collection of point sources each of which is imaged by a spread function. The object plane wave front is composed of deferent Fourier component plane waves travelling in direction associated with different spatial frequencies of objects light field reflected or transmitted. Each one of the Fourier plane waves interfere with reference wave on the photograph and reserves the information. When both reference waves and scattered object wavelet coming at angle , the relative phase of the waves varies from point to point and can be written as. $\frac{2\pi\, x \sin\emptyset}{\lambda}$ If two such waves have amplitude E0, the resultant field has amplitude

$E = 2\,\epsilon_0 \cos\frac{1}{2}\phi \sin(wt - kx - \frac{1}{2}\phi)$

And Irradiance distribution is given by

$= \frac{1}{2}\phi\, C\, \epsilon_0 (2\, E_o \cos\frac{1}{2}\phi)^2$

$= 2\, C\, \epsilon_0\, E_o^2 \cos^2\frac{1}{2}\phi$

$= C\, \epsilon_0 E_o^2 + C\, \epsilon_0 E_o^2 \cos^2\phi$

Hence we have a cosinusoidal distribution across the film plane. In monochromatic coherent beam is diffracted by the above hologram, the emerging beam has intensity of illumination proportional to I (x,y) $E_R(x,y)$ where $E_R(x,y)$ is the reconstructing wave incident on the hologram. Then $E_R(x,y) = E_{OR}\cos(2\pi\gamma t + \emptyset(x,y)$, $E_{OR}$ is the amplitude of the reconstructing wave. Therefore the final wave

$$E_F(x, y) = \frac{1}{2} E_{OR}(E_{OB}{}^2 + E_{OO}{}^2)\cos(2\pi\gamma t + \emptyset(x,y) + E_{OR}E_{OB}\, E_{OO} \cos(2\pi\gamma t + 2\emptyset - \emptyset o) + \frac{1}{2} E_{OR}E_{OB}\, E_{OO} \cos(2\pi\gamma t + \emptyset o)$$

E0R is the amplitude of the reference beam; E00 is the amplitude of the scattered wave from the object. Therefore the final wave consists of three parts:

1. Amplitude modulated version of the reconstructing wave. This is the zeroth order or undeflected direct beam. The other two are side band waves. These are the sum and difference terms. Among the side bands, the sum term represents a wave which has the same amplitude proportional to object wave $E_{OO}$ (x, y) and phase contribution $2\emptyset$ (x, y) arising from tilting background and reconstructing wave front at the plane of the hologram and it also contains the phase of the object. The difference term except for a multiplication constant has precisely the form of object $E_{00}$ (x, y) with the actual phase variation of the object. Hence this difference wave represents the scene exactly as it is and this is the phase modulated wavelet.

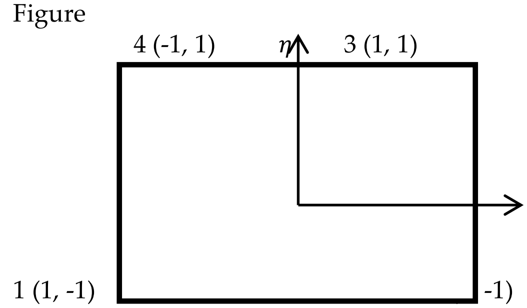
## FINITE ELEMENT DISCRETISATION

The primary image which is being interpolated and reconstructed is conveniently divided into several (N) finite elements preferably quadrilateral elements. The four corners of the quadrilateral are the four nodes of each such finite element. When the number of finite elements becomes large each finite element almost reduced into point size and it can be termed as pixel. Positions of nodes are labeled in terms of its x coordinate and y coordinates. If $(x_1, y_1)$, $(x_2, y_2)$, $(x_3, y_3)$ and $(x_4, y_4)$ are the coordinates of the nodes, the x and y coordinate of each interior point can be expressed in terms of shape function or interpolation function as $X = N_1X_1 + N_2X_2 + N_3X_3 + N_4X_4$.The shape functions $N_1$, $N_2$, $N_3$, $N_4$ can be expressed in terms of natural coordinates $\xi$ and $\eta$

As $N_1 = \frac{1}{4}(1+\xi\xi_1)(1+\eta\eta_1)$

Where ($\xi_2$, $\eta_2$ are natural coordinates of ith node and I can take values 1,2,3,4

Figure




For first node $\xi_1 = -1$, $\eta_1 = -1$ for second node $\xi_2 = 1 \eta_2 = -1$, third node $\xi_3 = 1$ $\eta_3 = 1$, and fourth node $\xi_4 = -1$ $\eta_4 = 1$, their coordinates in the shifted system and the static system are related by

$N_1 = \frac{1}{4}(1-\xi)(1-\eta)$

$N_2 = \frac{1}{4}(1+\xi)(1-\eta)$

$$N_3 = \frac{1}{4}(1+\xi)(1+\eta)$$

$$N_4 = \frac{1}{4}(1-\xi)(1+\eta)$$

If $\emptyset_1, \emptyset_2, \emptyset_3, \emptyset_4$ the phase changes of the object wave at node1, node 2, node 3 and node 4 respectively, at any interior point phase change can be expressed as: $\emptyset = N_1\emptyset_1+N_2\emptyset_2+N_3\emptyset_3+N_4\emptyset_4$

Low resolution images of a scene at different angles and different positions

Photograph of the specimen (or object) under study is taken at different angles and from different frames. It is preferable to use holographic techniques for photography. This is a two-step process. 1st step is recording the interference pattern generated by the interaction of scattered light from the object and the coherent reference beam. This is the hologram. The second stage is the formation of the image by diffraction of the coherent beam by the hologram.

By taking photographs of the same scene at different angles we get additional information about the scene. Hence the ambiguity in an image when we take asingle photograph can be removed by incorporating all the information from different images of the same scene. Also we have a 3D view that is the image is exactly same as the object is.

When we take photographs at different moving frames we have to make corrections for the displacement of the arbitrary chosen frames with respect to the standard static frame. The displacement can be described in terms of three parameters.

1. Displacement in the x direction (horizontal direction) $\Delta x$
2. Displacement in the y direction (vertical direction) $\Delta y$
3. The planar rotation $\emptyset$ If we take into account displacement in the x and y direction,

$x' = x+\Delta x$

$y' = y+\Delta y$

$x'$, $y'$ are x and y coordinates in the shifted frame and x,y are x and y coordinates in the static frame.

The effect of rotation can be incorporated by using matrix operator in the form

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\emptyset & -\sin\emptyset \\ \sin\emptyset & \cos\emptyset \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$x'$, $y'$are x and y coordinates in the rotated frame, x,y are x and y coordinates in the static frame. Correction is made for relative motion between the frames either due to the motion of camera or rotation of the frame supporting the camera. Then superimposing the low resolution images to the given reference plane we get the primary photograph from we seek to get high resolution images. This step is called registration.

## Interpolation by phase wavelets at selected frequencies

In this step the primary photograph is divided into several quadrilateral elements numbered from 1 to N, each quadrilateral elements has four nodes 1,2,3,4. For interpolation by phase wavelets we use a laser of fixed frequency and amplitude. The laser beam is being scattered from each of n finite elements or pixels. The scattered beam interferes with the reference laser beam. The above interference pattern is record in the hologram. The reference beam is diffracted from the hologram. The result is phase modulated wavelet. The phase modulated wavelet from each pixel is characterized by a particular phase depending on the pixel density. These phase modulated wavelets are digitalized and these signals are magnified.

## RECONSTRUCTION OF THE FINAL IMAGE AND THE RESULTS

The magnified digital signals from the various finite elements of the primary photograph are recombined. The final image is thus reconstructed. This image reconstruction can be done for different set of high frequencies. Super imposing these images we get the final images having the requisite qualities. We can use suitable algorithms for this reconstruction.

## CONCLUSION

It can be noted that all the information about the scene are contained in the primary images because we take photographs of the same scene at different angles and different positions. Since we use phase wavelets for interpolation we extract all the details of the primary photograph. Because the phase wavelets are digitalized and magnified and recombined, pixel density in the final image is very large. Hence we get high resolution image. Since we use laser beam of high frequency contrast factor is significant and the image will have super clarity. As the image is formed at the given frequency we get distortion less magnification and the image is true replica of the specimen. As a result of the holographic techniques, the image will have 3D view. Thus the image reconstructed on the basis of phase modulated wavelets is having high resolution, super clarity, distortion less magnification and 3D view.

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