Multifocus image fusion using Zernike moments

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ABSTRACT

A multifocus image fusion method using orthogonal moments is presented. The focus measure is based in the compute of Zernike and Harmonic moments of an image function. The algorithm divides the input images into blocks and evaluate the contrast of each block. From this, the boundaries between focused and defocused regions have been determined. The method selects the better focused regions to create the final focused image. The method is based on orthogonal basis functions, which are used as moment weighting kernel. Fusion results show that, Zernike-Fourier moments can achieve a high quality fusion. However, Harmonics moments achieve a good fusion with a simple average of moments.

Keywords: Zernike moments, orthogonal moments, image fusion

1. INTRODUCTION

Image fusion allows merging images from multiple sensors or even multiple images from the same sensor [1-2]. Its goal is to integrate complementary information to provide a composite image which could be used to better understanding of the entire scene. On the other hand, focusing cameras is an important problem in computer vision and microscopy, due to the limited depth of field of optical lenses in CCD devices. It is well known that, there are sensors which cannot generate images of all objects at several distances with equal sharpness. One way to overcome this problem is to take different in-focus parts and combine them into a single composite image which contains the entire focused scene. Many techniques have been used to generate fusion schemes [3-4], including the Wavelet transform [5]. In this context the fusion of microscope images is done along with an analysis of different sets of moments.

This work presents a block based algorithm for image fusion [6,7]. Zernike moments are used as a focus measure for evaluating the contrast or sharpness of a block o region. The algorithm identifies focused regions in an input image. Input images are fused by comparing the contrast by regions. Also, a fusion scheme based on the average of Harmonic moments is presented.

2. A THEORETICAL REVIEW

2.1 Image moments

A general expression for the orthogonal moments A_{nl} of order n and repetition l for an image function $f(r,\theta)$ in polar coordinates is [8],

$$|A_{n,l}| = \left| \frac{g}{u^2} \int_0^{2\pi} \int_0^u f\left(\frac{r}{u},\theta\right) \Psi_{n,l}\left(\frac{r}{u},\theta\right) r dr d\theta \right|. \tag{1}$$

where u and g are factors that represent the scale and intensity of an image function.

If $\Psi_{n,l}(r,\theta) = R_{n,l}(r)e^{i\theta}$ then the invariant Zernike moments $|Z_{n,l}|$ of radial and angular orders n, l are computed. The radial polynomials are defined as [9],

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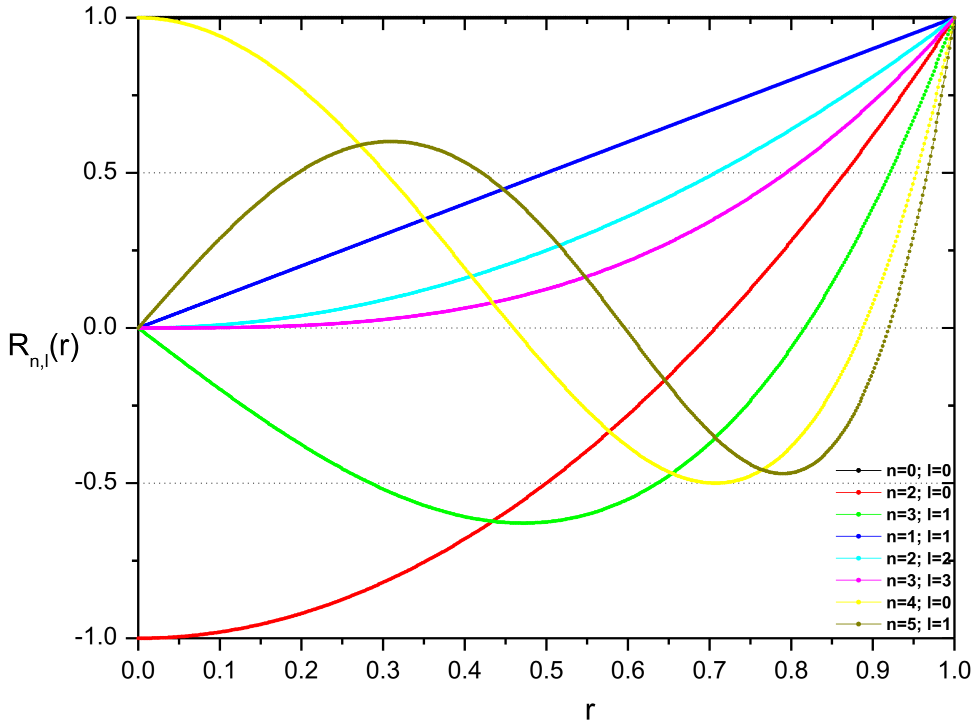

Figure 1. Zernike polynomials.

$$R_{n,l}\left(\frac{r}{u}\right) = \sum_{s=0}^{\lfloor \frac{n-|l|}{2} \rfloor} (-1)^s \frac{(n-s)!}{s!(\frac{n+|l|}{2}-s)!(\frac{n-|l|}{2}-s)!} \left(\frac{r}{u}\right)^{n-2s}, \tag{2}$$

and $n \geq 0$, $l = 0, \pm 1, \pm 2, ...$ Conditions are that $n - |l|$ must be an even number and $|l| \leq n$.

The orthogonality property is expressed by,

$$\int\int_{r\leq 1} \Psi^*_{nj}(r,\theta)\Psi_{li}(r,\theta) r dr d\theta = \frac{\pi}{n+1}\delta_{nl}\delta_{ij}, \tag{3}$$

where

$$\delta_{ij} = \{ \begin{array}{ll} 1 & if \quad i = j \\ 0 & otherwise \end{array} \tag{4}$$

is the delta of Kronecker. Figure 1 shows the graphs of the first Zernike polynomials.

If $\Psi_{n,l}(x,y) = sin(nx\pi)sin(ly\pi)$ then the cartesian Harmonic moments $H_{n,l}$ of an image function $f(x,y)$ are computed.

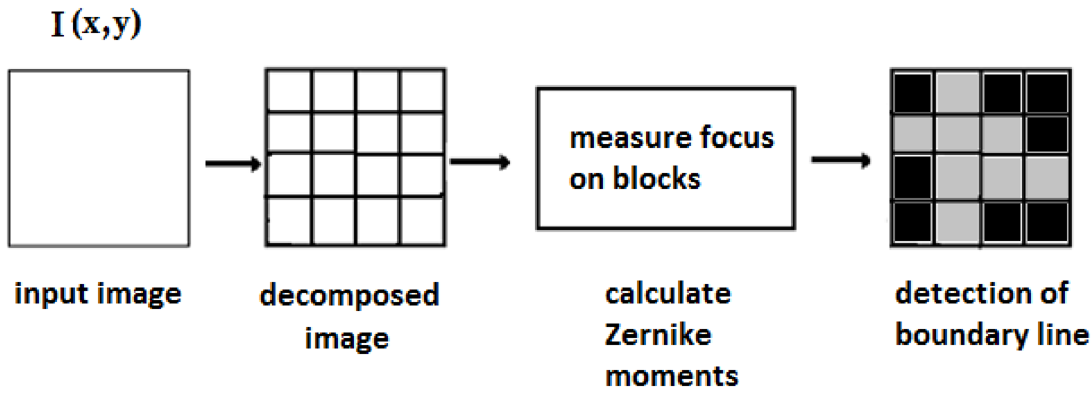

Figure 2. Diagram for detection of boundaries between focused and defocused regions.

2.2 Image reconstruction

Image reconstruction of $f^R_{x,y}$ from Zernike moments Z_{nl} is defined as [8],

$$f^R_{i,j} = \sum_{n=0}^{Max_n} \sum_{l=0}^{Max_l} Z_{nl} R_{n,l}(r_{i,j}) e^{i\theta_{i,j}}. \tag{5}$$

and

$$f^R_{i,j} = \sum_{n=0}^{Max_n} \sum_{l=0}^{Max_l} H_{nl} sin(nx_i \pi) sin(ly_j \pi). \tag{6}$$

from Harmonic moments.

3. IMAGE FUSION SCHEME

3.1 Detection of focal planes

In this section will be used the Zernike moments into a focus measure as shown in the Figure 2. The input image I is decomposed into blocks of size $M \times N$. Zernike moments are computed for each ith block as a focus measure, and denoted by $|Z^i_{n,l}|$. From this, the boundary line between focused and defocused regions is given by,

$$Boundary^i_{n,l} = \{ \begin{array}{ll} 0 & if \quad |Z^i_{n,l}| < \mu^i \\ k_i & otherwise \end{array} \tag{7}$$

where k is an intensity value and μ^i denotes the mean of Zernike moments $|Z^i_{n,l}|$ of the ith block .

3.2 Digital image fusion using Zernike moments

In this case, the fusing of two images $I1$ and $I2$ using Zernike moments is consider. The fused image is generated as follows.

1. Finds out boundaries between focused and defocused regions.
2. Compute Zernike moments of each region of $I1$ and $I2$.
3. Compare the Zernike moments of each region of $I1$ and $I2$ and construct the fused image as,

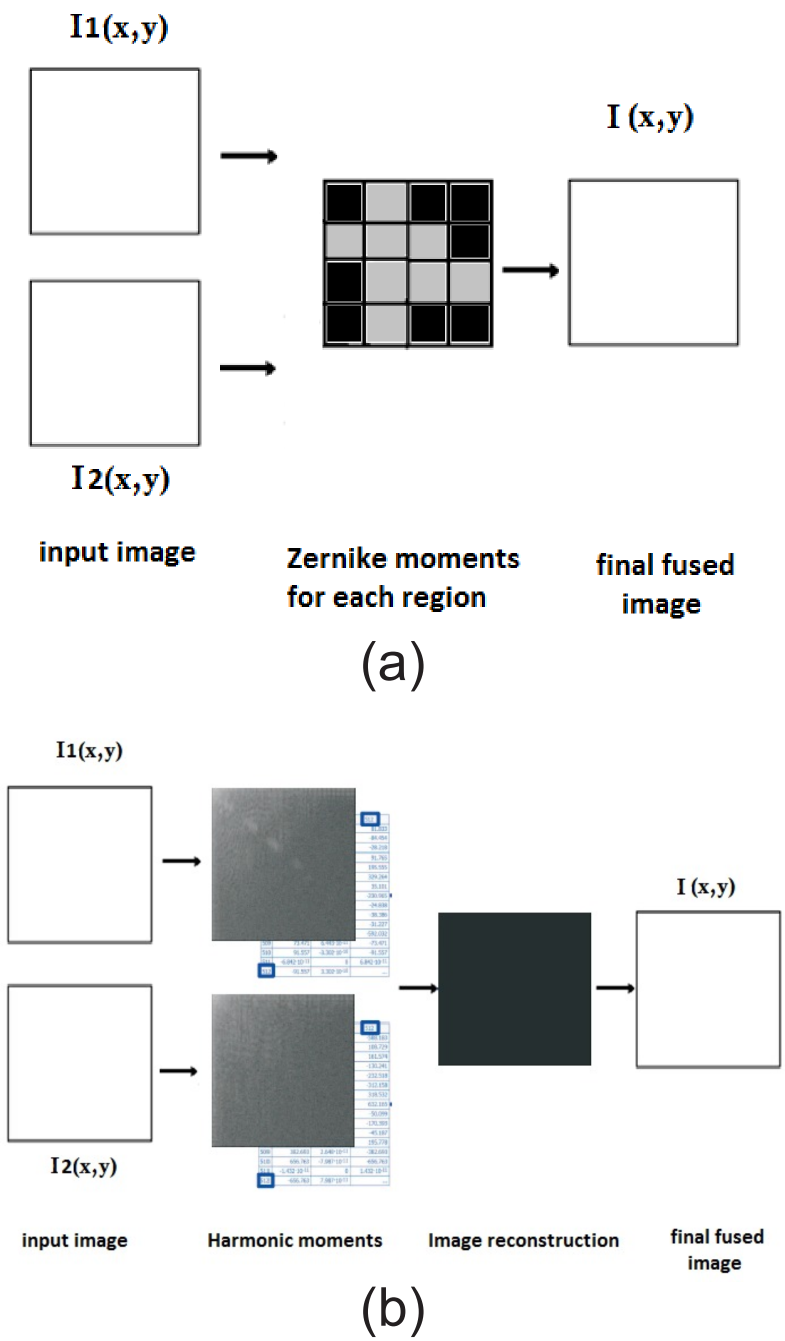

Figure 3. Fusion scheme using (a) Zernike and (b) harmonic moments.

$$F(region) = \begin{cases} I1 & if \quad |Z^{I2}_{n,l}(region)| < |Z^{I1}_{n,l}(region)| \\ I2 & otherwise \end{cases} \quad (8)$$

In the Figure 3(a) the fusion scheme using Zernike moments is shown.

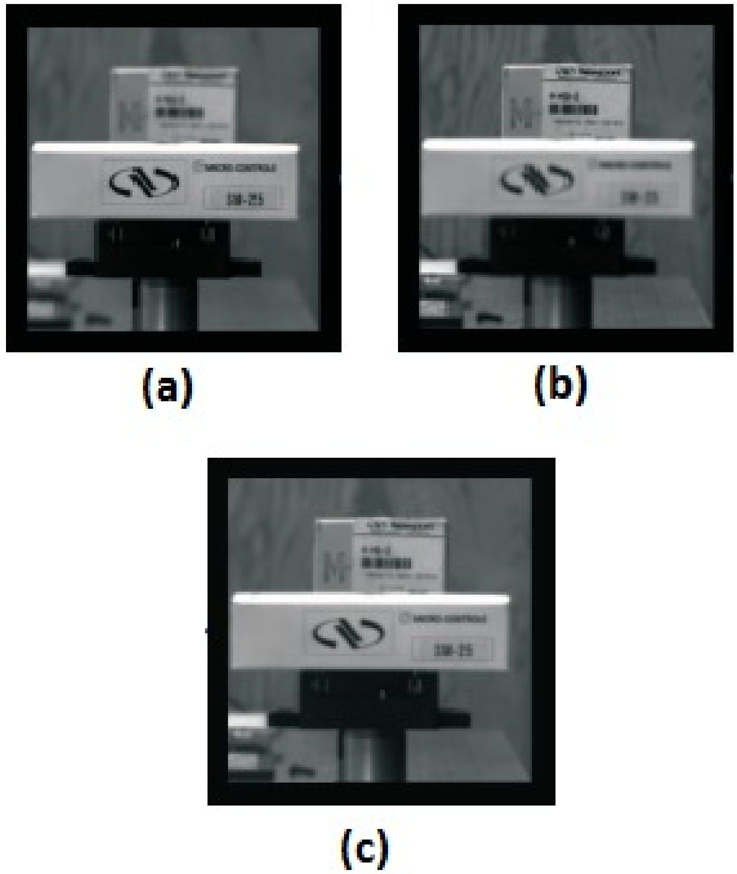

Figure 4. Multi-focus input images with focus (a) at the first plane, (b) at the second plane. (c) fused image using Harmonic moments.

3.3 Digital image fusion using Harmonic moments

Again, the fusing of two images $I1$ and $I2$ is consider. The fused image using Harmonic moments is generated as follows.

1. Compute Harmonic moments $H_{n,l}^{I1}$ and $H_{n,l}^{I1}$ of $I1$ and $I2$.
2. Construct the fused image as,

$$H_{n,l}^{f} = \frac{H_{n,l}^{I1} + H_{n,l}^{I2}}{2} \tag{9}$$

3. Reconstruct the fused image.

In the Figure 3(b) the fusion scheme using Harmonic moments is shown.

4. EXPERIMENTAL RESULTS

The first experiment has been performance on a scene that contains two objects. The test images used here were taken by using an optical system with focus at two planes. Figure 4(c) shows the result on fusing images 4(a) and 4(b) using Harmonic moments.

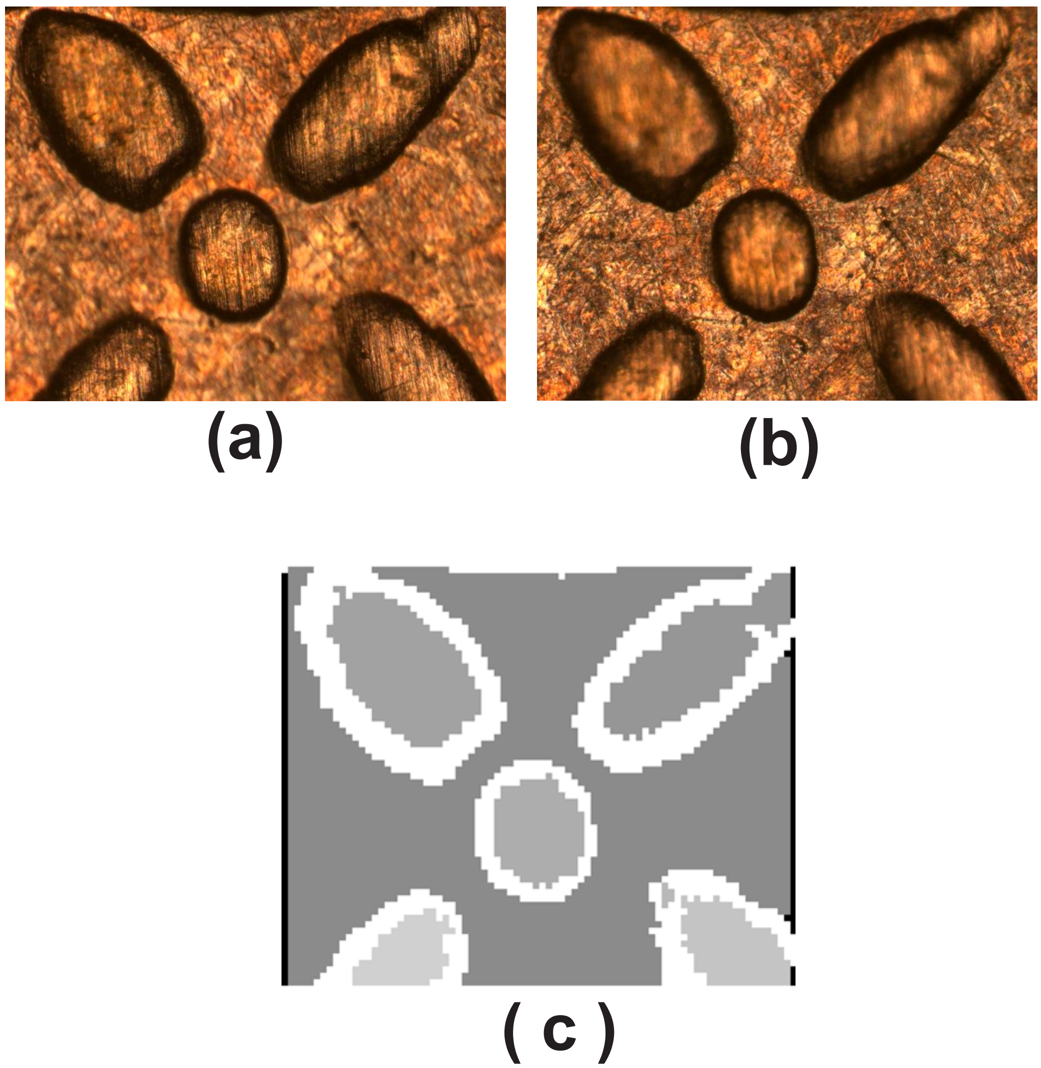

Figure 5. "Glifo" section with amplification of 10X used as test object (a) focused on the top, (b) focused on the botton and (c) Boudary line obtained from (a).

The test images used here were taken by using an optical microscope system. A microscope image is presented in the Figure 5. The images are obtained from a coin, by inspection of its surface. The illumination of the sample is done by a metal Halide machine vision illuminator. Non polarizing light is used. The fusion of microscope images were done in the HSI (Hue, Saturation, Intensity) color space. Only the intensity information were processed. In the Figure 5(c) is shown the resulting boundary line for image segmentation.

Figure 6 describes the gradual fusion of the better focused regions. This regions were selected using the maximum value of Zernike moments from input images. The final fused image is shown in the Figure 7. The results show that the proposed method create a fused image with better contrast that corresponding defocused regions.

The figure 8 shows test images taken from a metal surface by using an optical system with focus at two planes. Figure 8(c) shows the result on fusing images 8(a) and 8(b) using Zernike moments. Finally, Figure 9 shows test images taken by using an optical system with focus at three planes. Figure d(c) shows the result on fusing images 9(a), 9(b) and 9(c) using the method of Zernike moments.

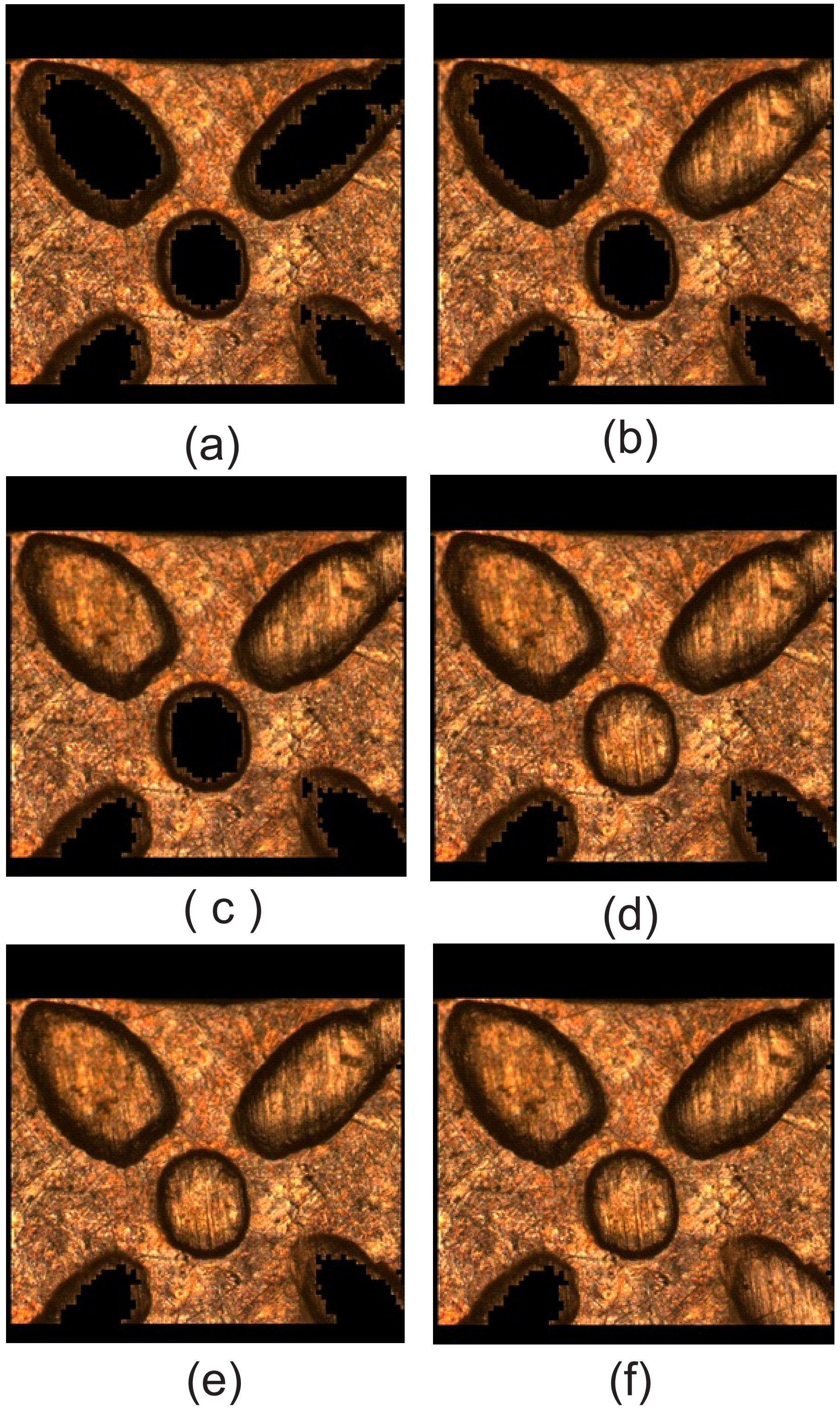

Figure 6. Gradual fusion of the better focused regions using the maximum value of Zernike moments from input images.

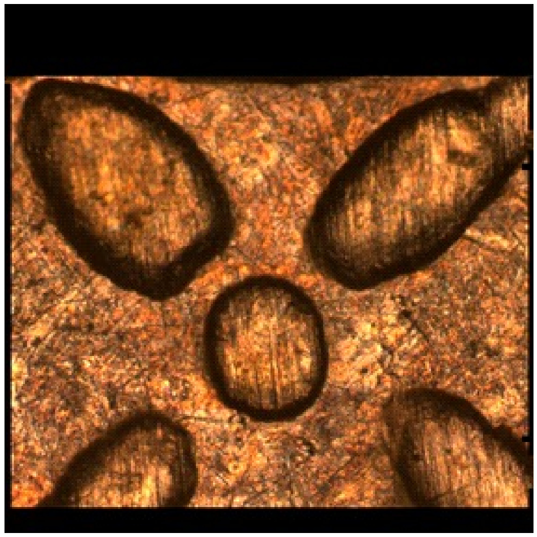

Figure 7. Final fused image with better contrast that corresponding defocused regions.

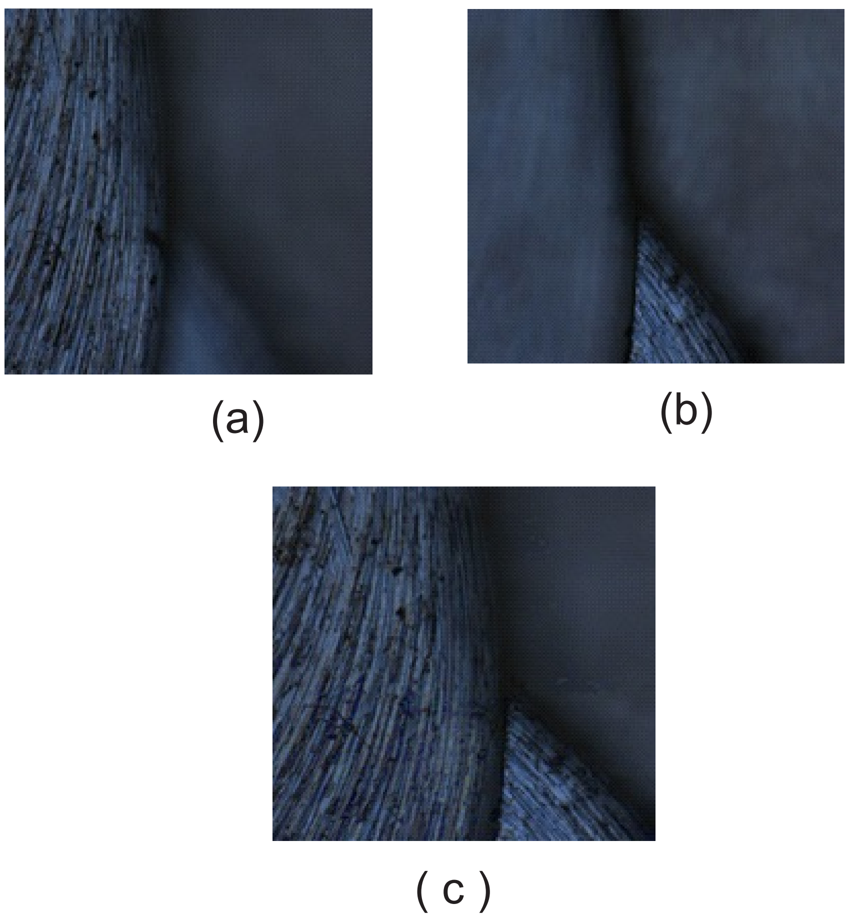

Figure 8. Multi-focus input images with with focus (a) at the first plane, (b) at the second plane. (c) fused image using Zernike moments.

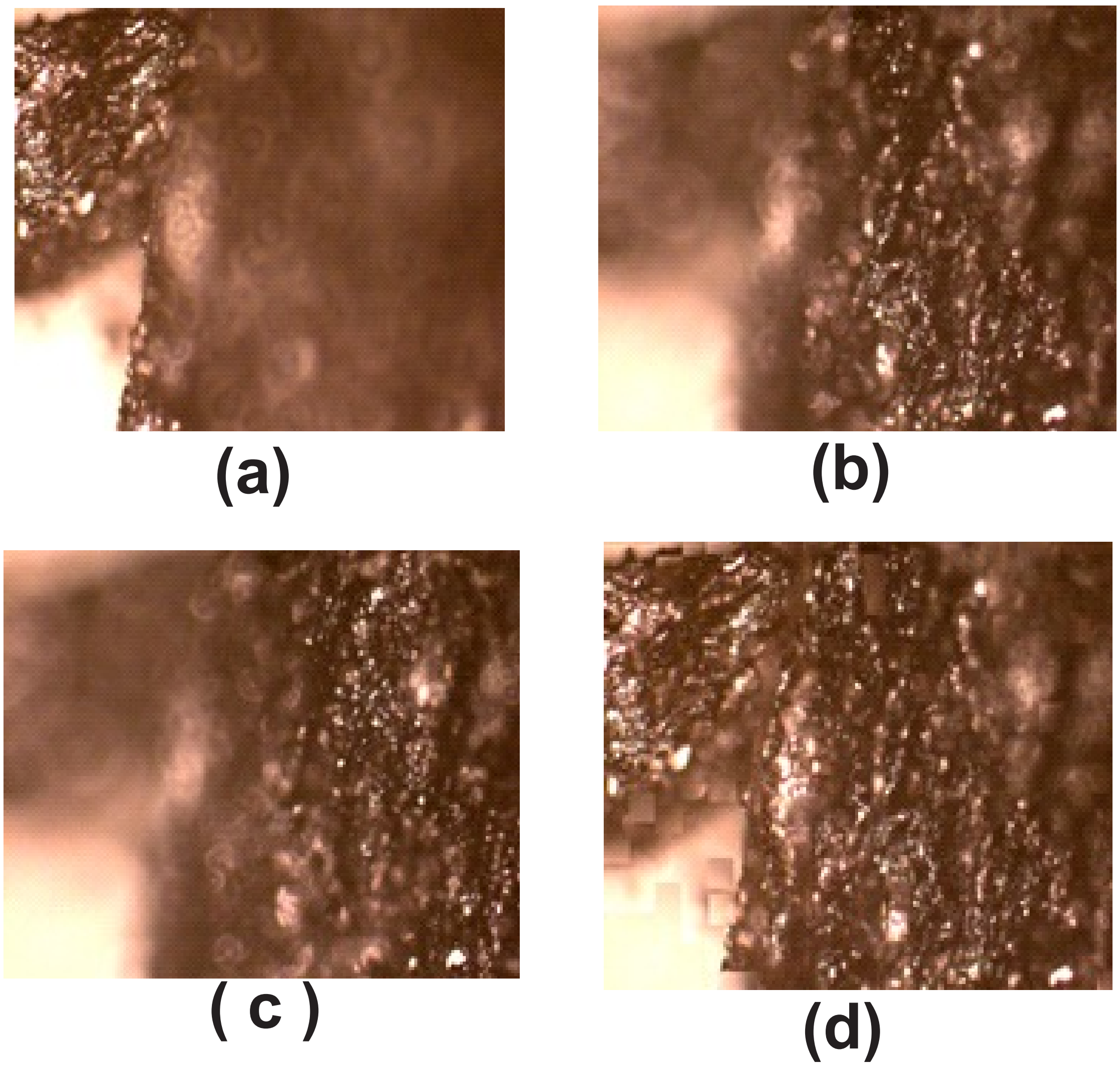

Figure 9. Multi-focus input images with (a) near, (b) middle and (c) far focused regions. (c) Fused image using Zernike moments.

5. CONCLUSIONS

A new algorithm for muti-focus image fusion has been proposed. The focus measure is based in the compute of orthogonal Zernike and Harmonic moments of an image function. The algorithm divides the input images into blocks and evaluate the contrast of each block. From this, the boundaries between focused and defocused regions have been determined. The method selects the better focused regions to create the final focused image. The fusion of microscope images were done in the HSI (Hue, Saturation, Intensity) color space. Only the intensity information were processed. The results show that the method based on Zernike-Fourier moments create a fused image with better contrast that corresponding defocused regions. In the case gray level images, Harmonics moments achieve a good fusion with a simple average of moments from the input images.

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