# Multi-focus microscope image fusion analysis based on Daubechies Wavelets

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## ABSTRACT

We present in this work a multifocus image fusion algorithm based on wavelet transforms applied to multi-focus microscopy images acquired by the bright-field technique. The fusion scheme is based on the Daubechies family transforms. Experimental results are presented using metallic samples.

**Keywords:** Multifocus Image fusion, Daubechies wavelets, image analysis, Microscope images.

## 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]. This last technique is practicable when a pyramidal algorithm is added. In this context the fusion of microscope images is done along with an analysis of the performance of all kernels.

## 2. THE DAUBECHIES WAVELET TRANSFORMS. A BRIEF REVIEW

In this section the basic mathematical concepts on Wavelet analysis are reviewed, useful in the developing of image fusion algorithms. These concepts are related with a historically mathematical tool, the so-called Wavelet transform. From the mathematical point of view, a wavelet $\psi(x)$ is a measurable real function with compact support, and square-integrable on the real line. In wavelet analysis a prototype function is adopted which is called the basic wavelet. A set of wavelet basis functions $\{\psi_{a,b}(x)\}$, can be generate by translating and scaling of the basic wavelet as,

$$\psi_{a,b}(x) = \frac{1}{\sqrt{a}}\psi\left(\frac{x-b}{a}\right), \tag{1}$$

where $a > 0$ and $b$ are real numbers. So that, the Daubechies family of orthonormal wavelet bases for the space of square-integrable functions can be defined by

$$\psi_{m,n}(x) = \frac{1}{\sqrt{2^m}}\psi\left(\frac{x}{2^m} - n\right), \tag{2}$$

$m, n \in Z$. As in Eq. (2), each member of this family consists of the dyadic dilations and integer translations of a compactly supported wavelet function $\psi(x)$. The wavelet function is derived by a scaling function $\varphi(x)$, which also has compact support and is defined by

$$\varphi(x) = \sum_{k=0}^{2g-1} a_k \varphi(2x - k), \tag{3}$$

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in where $g \epsilon Z^{+}$, and the coefficients $a_0, a_1, \cdots, a_{2g-1}$ define a discrete Wavelet system denoted by *DbN*. These wavelet filter coefficients satisfy orthogonality conditions. Moreover, the set of coefficients

$$b_k = (-1)^k a_{2g-1-k} \,, \tag{4}$$

for $k = 0,1,\cdots,2g-1$ , defines the wavelet function $\psi(x)$ associated with the scaling function of the wavelet system as follows,

$$\psi(x) = \sum_{k=0}^{2g-1} b_k \varphi(2x-k). \tag{5}$$

Particularly when $g = 1$, the coefficients are uniquely determined and are equal to,

$$\begin{pmatrix} a_0 \\ a_1 \end{pmatrix} = \begin{pmatrix} 0.707 \\ -0.707 \end{pmatrix}. \tag{6}$$

Similarly when $g = 2$, the coefficients set is

$$\begin{pmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{pmatrix} = \begin{pmatrix} \frac{1+\sqrt{3}}{4\sqrt{2}} \\ \frac{3+\sqrt{3}}{4\sqrt{2}} \\ \frac{3-\sqrt{3}}{4\sqrt{2}} \\ \frac{1-\sqrt{3}}{4\sqrt{2}} \end{pmatrix}.$$

The discrete Wavelet systems are respectively denoted by *Db2* and *Db4*. All the coefficients of the Daubechies family are graphed in the Fig. 1.

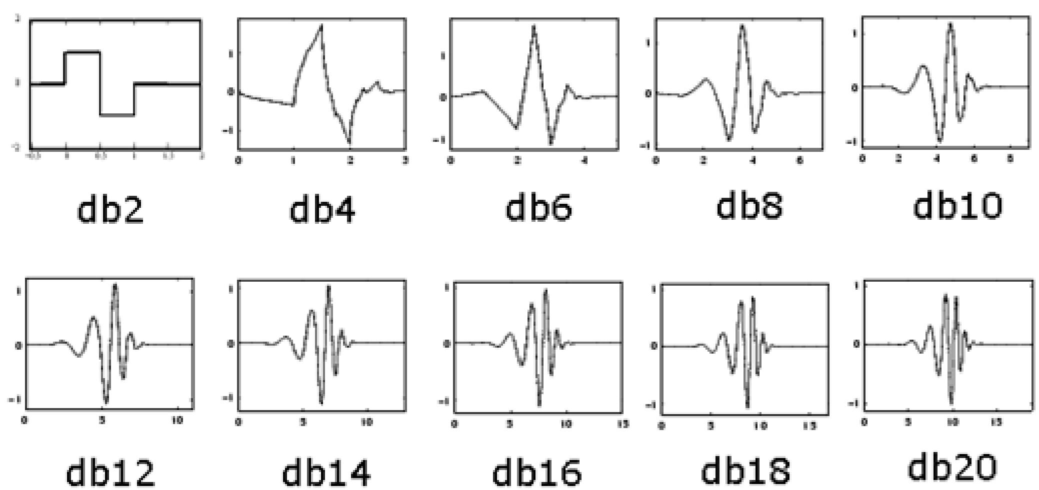
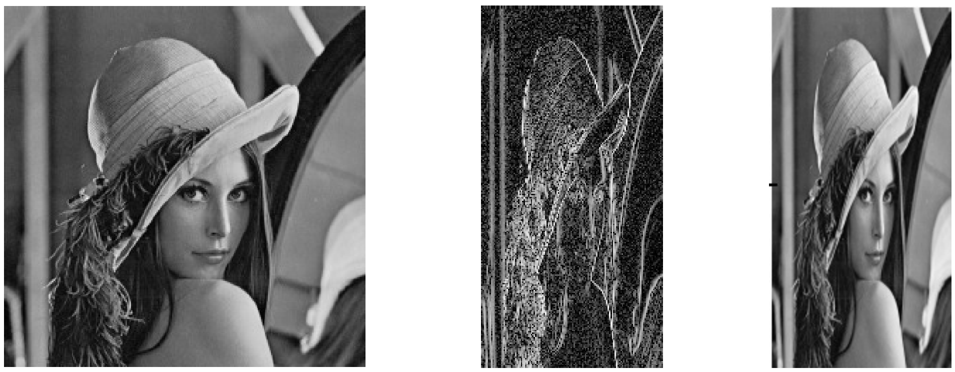



Figure 1. The Daubechies family kernels to produce the Wavelet transform

To produce practical wavelet transform is required to define the generalized product or product of order *p*, between matrices and vectors of any number of rows and columns. The product of order *p=2,* can be used to multiply the data matrix of the image of Fig. 2a, versus the coefficient vector defined in Eq. (6). The result is shown in the Fig. 2b. Also in the same Figure is shown the product of order *p=2*, between the image and the coefficients,

$$\begin{pmatrix} b_0 \\ b_1 \end{pmatrix} = \begin{pmatrix} 0.707 \\ 0.707 \end{pmatrix}. \tag{7}$$

In the two cases the product comprises the output images, and extracts different information of the input images. In the first product the high frequencies are extracted and in the second the low frequencies are visible.



a) b) c)

Figure 2. a) Input image, b) Image transformed by the coefficients of Eq. (6), c) Image transformed by the coefficients of Eq. (7)

Using two-dimensional and three levels of transformation, the wavelet transform can be seen as shown on the Figure 3. Here a pyramidal algorithm to reduce the number of operations has been implemented.

## 3. IMAGE FUSION SCHEME

In this section will be used the Daubechies transform into a fusion scheme $\phi$ as shown in the Figure 4. The input images are transformed by the Daubechies wavelet transform $w$ and by means the fusion criterion the coefficient transforms are fused. The fusion rule consists of the maximum values of the coefficients obtained by the transformation for each image. By means the inverse wavelet transform $w^{-1}$ the output fusion image is obtained. This process can be compacted by,

$$F(i,j) = w^{-1}(\phi(w(A(i,j)), w(B(i,j)))) \quad . \tag{8}$$

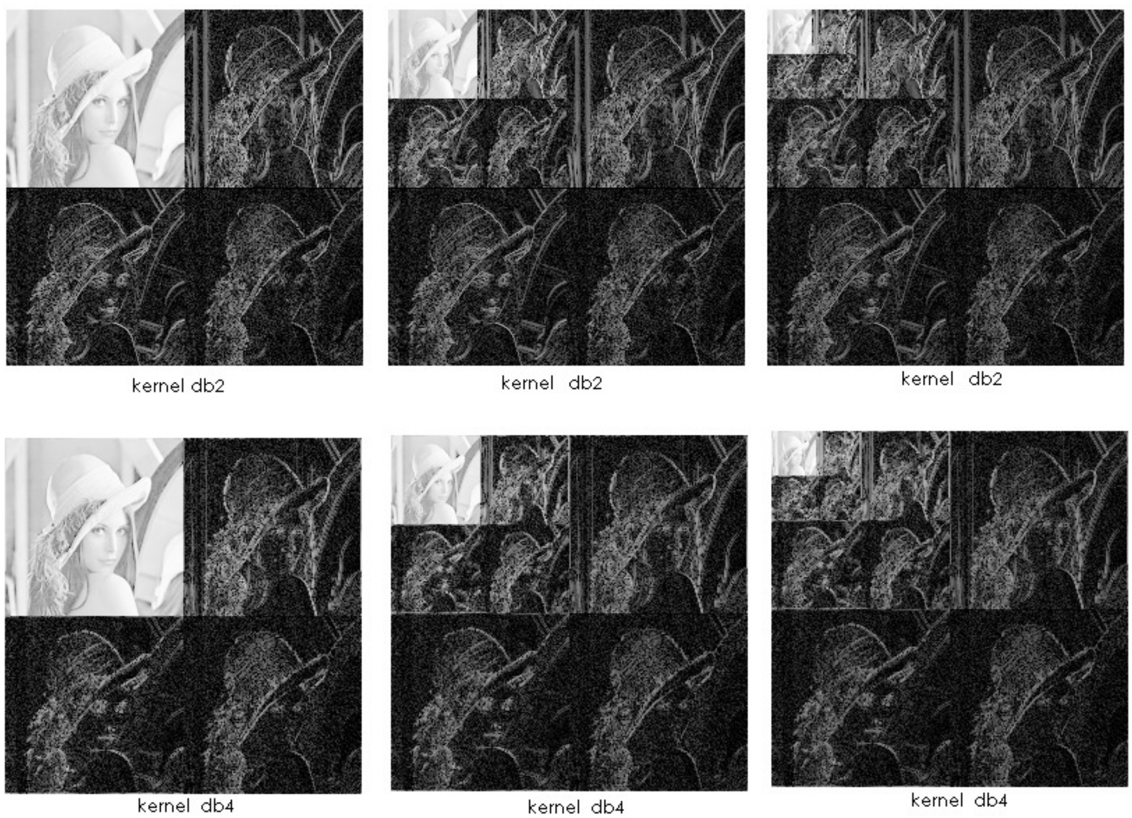



Figure 3. Wavelet transform of the “lena” image. Two kernels and three levels are used.

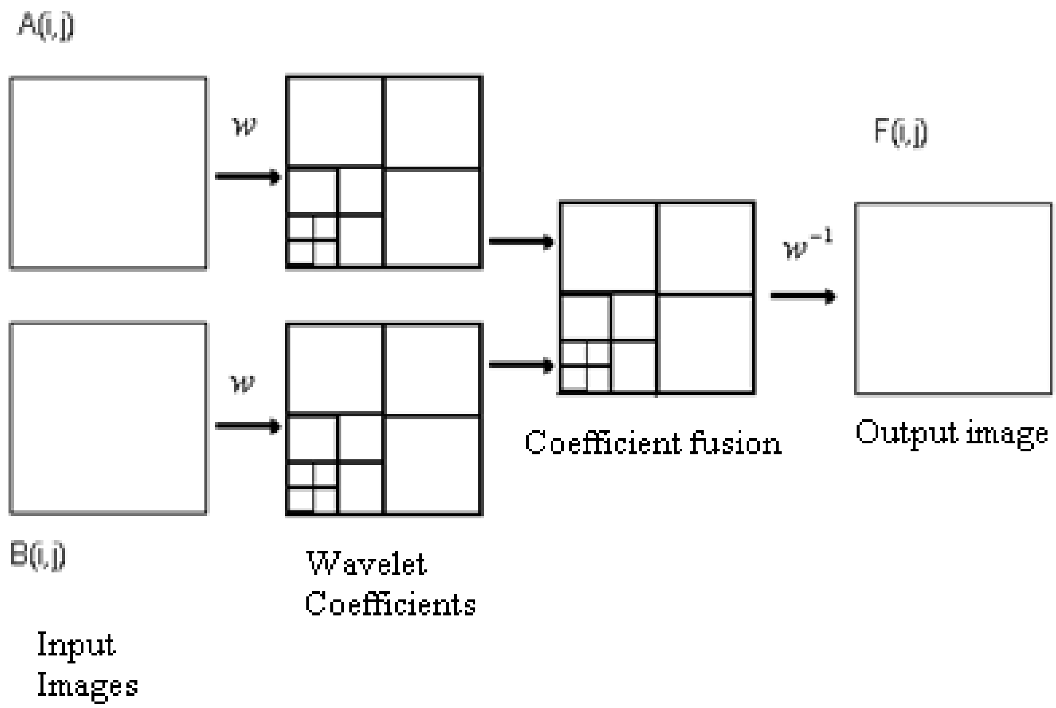



Figure 4. Sketch of the image fusion scheme

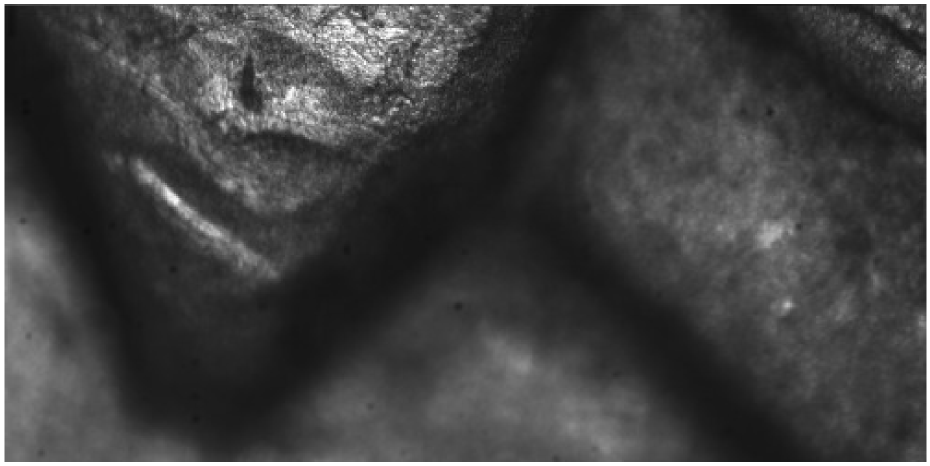
## 4. OPTICAL SETUP

The test images used here are taken by an optical microscope system as shown in the Figure 5. Three samples of microscope images are presented in the Figure 6. 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 optical system has a ½ in. CCD B&W camera (1392×1040 px) with a video frame rate of 150 frames/s. and a monochrome frame grabber with video up to 60 MHz of pixel rate and a pixel resolution up to 2048×2048.

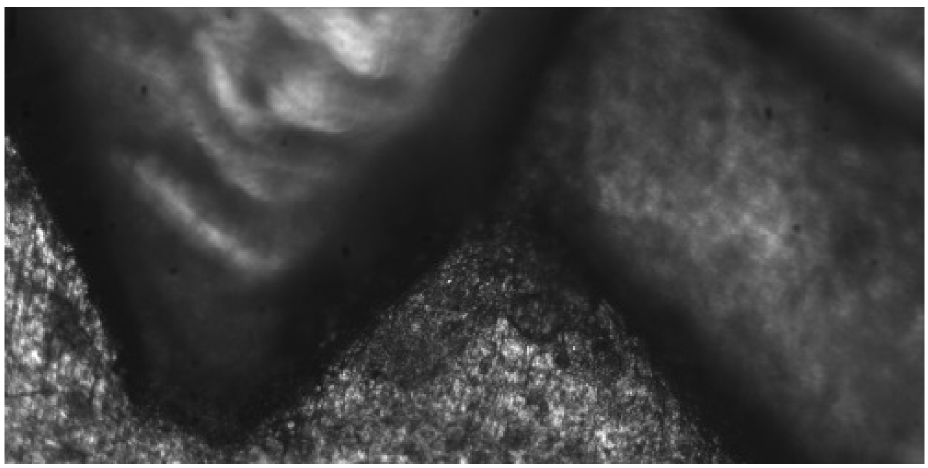

Figure 5. Optical microscope system, CCD camera, and computer. The sample is a metallic key.

## 5. RESULTS

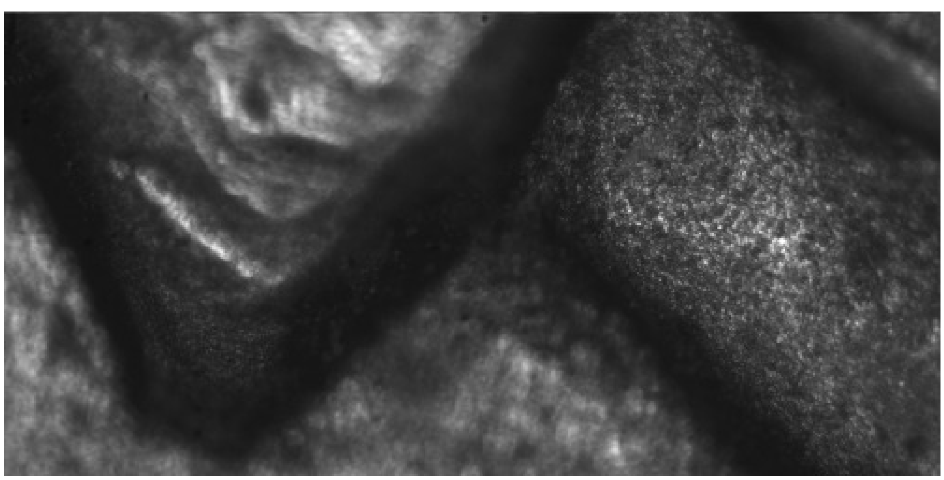
Digital images are taken from different in-of-focus and out-of-focus planes using the optical system of the Figure 5. Three photographs of the sample at different focus are shown in the Figure 6, where different zones can be focused, not at the same time. As it is explained in the section 3, the Daubechies wavelet transforms are obtained and by the fusion scheme only one image is merged as shown in the Figure 7. The fused image contains complementary information of the three images, although it is an approximation of the overall.



a)



b)



c)

Figure 6. Multifocus Images from the same scene of a metallic sample (coin). The focus is taken in three different planes of the sample. The M plan Apo NIR objective is 10X/0.26. *f=200.*

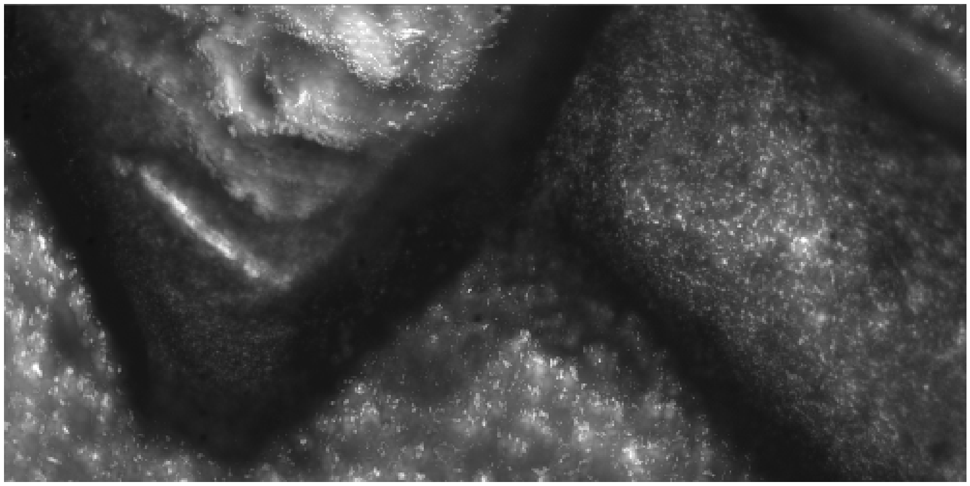


Figure 7. Microscope Image Fusion by means the wavelet transforms of the input images taken from the Figure 6.

## 6. CONCLUSIONS

A fusion scheme is presented by means the Daubechies Wavelet transform, the kernels used are Db(2) and Db(4). The kind of images is acquired from the microscope images of a metallic sample. The Daubechies wavelet transform performance is depended on the input images, so that the fusion criterion can substituted. The pyramidal algorithm along with a fusion scheme can be implemented into the acquisition microscope system to improvement on the vision in the microscope.

## 7. ACKNOWLEDGMENTS

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