



ISSN: 0067-2904

Optical Images Fusion Based on Linear Interpolation Methods

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Abstract

Merging images is one of the most important technologies in remote sensing applications and geographic information systems. In this study, a simulation process using a camera for fused images by using resizing image for interpolation methods (nearest, bilinear and bicubic). Statistical techniques have been used as an efficient merging technique in the images integration process employing different models namely Local Mean Matching (LMM) and Regression Variable Substitution (RVS), and apply spatial frequency techniques include high pass filter additive method (HPFA). Thus, in the current research, statistical measures have been used to check the quality of the merged images. This has been carried out by calculating the correlation and some traditional measures of the images before and after the integration process. Results showed that the adopted fusion process and statistical measures have efficiently and qualitatively determined the preference of images after the merge process and indicated which techniques are the best and estimation homogenous regions.

Keywords: interpolation methods, statistical standard, correlation, fusion techniques, optical image.

دمج الصور البصرية بالاعتماد على طرق الاستكمال الخطي

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الخلاصة

دمج الصور أحد أهم التقنيات المعتمدة في تطبيقات الاستشعار عن بعد ونظم المعلومات الجغرافية. في هذه الدراسة، تم عمل محاكاة باستخدام الكاميرات عملية دمج الصور البصرية من خلال إعادة تحجيم الصور بطرق الاستيفاء (الجوار الأقرب nearest، الجوار ثنائية الخطية bilinear والجوار المكعبة bicubic) وتطبيق تقنيات الدمج على الصور التي تم استعادة تحجيمها مع الصورة الرمادية والتي تشمل التقنيات الإحصائية المتمثلة (LMM, RVS)، وكذلك تقنية الدمج المعتمدة على التردد المكاني (HPFA)، تم فحص جودة الصور قبل وبعد عملية الدمج من خلال حساب مقاييس الارتباط (CC)، المتوسط (μ)، الانحراف المعياري (STD)، المعلومات المتبادلة (MI)، التردد المكاني (SF)، وكذلك معدل الخطأ المطلق (AMSE). وأظهرت النتائج كفاءة عالية وفعالة لعملية الدمج والمقاييس الإحصائية المعتمدة كما وحددت أي التقنيات المعتمدة هي الأفضل وتحديد التفاصيل الدقيقة جدا في المناطق المتجانسة.

1. Introduction

Image fusion is the process of merging relevant information from two or more images into a single image that is more informative than any of the original images. Image fusion can be classified into three categories: pixel level, feature level, and resolution level [1, 2].

Increasing of the number and variety for the data obtained from the sensors carried on satellites, which differ in attitude, scanning angle, and resolution (temporal, spectral, spatial, radiometric)...etc. produce geometric and radiometric problems to work with data collected from different satellites or from the same satellite but at different time[3].

To align a group of images taken for the same location so that each pixel in every image represent the same location on the map, the geometric distortion must be resolved, this process of geometric rectification is usually called the registration process, which is, in fact, a kind of deformation (warping) process so that a group of images has the same geometry. Image registration of remotely sensed data is an important step, as far as is often necessary to compare data taken at different times on a basis-to-point basis, is for many applications (such as studying time changes). So we need to obtain a new set of data is recorded in a way image conversion under suitable geometry transformation with previous dataset [4,5]. Images obtained by the sensors satellite -board by a number of distortions, which if left without correction would affect the accuracy of the extracted information and thereby reduce the utility of the data affected. These distinctions can be measured globally by two categories: geometrical, and radio metrical distortions [5, 6]. Many previous studies have been carried out in the field of image integration using different criteria to check the quality of the merged images [7- 9]. Although images merging process has been widely used in different applications and many criteria for checking the quality of the merged images have been utilized in different previous studies, still, there is no clear measure to check the quality and efficiency of the merged images.

In this study, merging techniques based on interpolation methods have been adopted as important and efficient techniques to merge images. Also, statistical measures have been developed to check the image quality and measure quality inspection by correlation measure and some statistical measures before and after the integration process. This method has been used to determine image details quality especially tiny detail, estimate homogenous in different regions, the optimal image and identify the best technique used in this study employing different statistical measurements.

2. Resampling for Geometric Transformation

There are many resampling models for geometric transformation, which differ by the behavior of the curve that represent the weighting coefficients for the resampling process, in which the value of every pixel in the image (i,j) must be computed. Niblack [10] had mentioned the following a linear behavior for the resampling process can be summarized as follow [10]:

1. Map (x,y) to the input image using bilinear interpolation on the grid to produce (k,l) Although (x,y) is an integer location, in general (k,l)is fractional.
2. If point (k,l) falls outside the input image (k is less than 1or greater than the number of samples) set the pixel brightness value(BV) to a fill character,(say black).
3. Otherwise at point (k,l) , perform a resampling (such as nearest neighbor, bilinear interpolation, or cubic convolution)to produce BV.

In two dimensions, these may be written as [10]:

Nearest Neighbor

$$BV = BV_{in}(x', y'), \dots \dots \dots (1);$$

Where X'=round (k), Y'=round (l).

Bilinear Interpolation

$$t_1 = bi(BV_{in}(X, Y), BV_{in}(X + 1, Y), c), \dots \dots \dots (2)$$

$$t_2 = bi(BV_{in}(X, Y + 1), BV_{in}(X + 1, Y + 1), c), \dots \dots \dots (3)$$

$$BV = bi(t1, t2, d) \dots \dots \dots (4)$$

Cubic Convolution

$$t_1 = cc(BV_{in}((X - 1), (Y - 1)), BV_{in}((X - 1), Y), BV_{in}((X - 1), (Y + 1)), BV_{in}((X - 1), (Y + 2)), c), \dots \dots \dots (5)$$

$$t_2 = cc(BV_{in}(X, (Y - 1)), BV_{in}(X, Y), BV_{in}(X, (Y + 1)), BV_{in}(X, (Y + 2)), c), \dots \dots \dots (6)$$

$$t_3 = cc(BV_{in}((X + 1), (Y - 1)), BV_{in}((X + 1), Y), BV_{in}((X + 1), (Y + 1)), BV_{in}((X + 1), (Y + 2)), c), \dots (7)$$

$$t_4 = cc(BV_{in}((X + 2), (Y - 1)), BV_{in}((X + 2), Y), BV_{in}((X + 2), (Y + 1)), BV_{in}((X + 2), (Y + 2)), c), \dots (8)$$

$$BV = bi(t_1 t_2, t_3, t_4, d) \dots (9)$$

Where

$X=Round(x)$, $Y=Round(y)$; $c=x-X$; $d=y-Y$; The bi and cc are the bilinear and cubic convolution interpolation functions defined as follows: [10]

$$bi(y_1, y_2, d) = y_1(1-d) + y_2d \dots (10)$$

and

$$cc(y_1, y_2, y_3, y_4, d) = y_2 + d((-y_1 + y_2) + d((2y_1 - 2y_2 + y_3 - y_4) + d(-y_1 + y_2 - y_3 + y_4)) \dots (11)$$

Assign the output pixel at (x, y) the value BV . While, Jensen [10], had used more coarse behavior (away from linearity) for the curve of the weighting coefficients of the re sampling process, where the equations he used for the re sampling can be defined as follows:

Bilinear Interpolation:

$$v = \frac{\sum_{k=1}^4 \frac{Z_k}{D_k^2}}{\sum_{k=1}^4 \frac{1}{D_k^2}}, \dots (12)$$

$$v = \frac{\sum_{k=1}^{16} \frac{Z_k}{D_k^2}}{\sum_{k=1}^{16} \frac{1}{D_k^2}}, \dots (13)$$

Where Z_k are the surrounding data point values, which either four points (first neighbors) in the case of bilinear interpolation or sixteen points (first and second neighbors) in case of cubic interpolation, and D_{2k} are the distances squares from the point inquisition to these data points.

For more accurate resampling process some researchers like Bourke [11], had used more complicated functions in comparison with linear behavior to describe the curve of weighting coefficients of the resampling process, which is called Bicubic resampling, although this kind of resampling demands very long computational time compared to the previous re sampling models, but it has some superior features that make it more desirable, they are [11]:

- a. Bicubic interpolation improves the brightness function model by approximating it locally by a multiline surface. Uses 16 neighbor points for interpolation.
- b. The definition of core interpolation ('Mexican Hat')

$$h'_3(t) = \begin{cases} (1 - 2|t| + |t|^2), & \text{if } |t| < 1 \\ 4 - 8|t| + 5|t|^2 - |t|^3, & \text{if } 1 \leq |t| < 2 \\ 0, & \text{otherwise} \end{cases}, \dots (14)$$

$$h_3(x, y) = h'_3(x)h'_3(y), \dots (15)$$

Where $h_3(x, y)$ is the behavior of the curve of the weighting coefficients of the resampling process.

- c. Bicubic interpolation does not suffer from a boundary problem such as nearest neighborhood interpolation and adjust with linear interpolation blurring again.
- d. Bicubic interpolation is often used in raster displays that enable zooming to an arbitrary scale.

Bicubic interpolation maintains fine detail in the image very well. The formula below gives the interpolated value; it is applied to each of the red, green, and blue components. Stretch (m) and (n) to a 4×4 grid around pixels (i, j) [11]:

$$F(x', y') = \sum_{m=-1}^2 \sum_{n=-1}^2 F((x + m), (y + n)) * (R(m - dx)) * (dy - n), \dots (16);$$

The cubic weighting function $R(x)$ is given as in the equation (17) [11]:

$$R(x) = \frac{1}{6} [(p(x + 2))^3 - 4p(x + 1)^3 + 6p(x)^3 - 4p(x - 1)^3] \dots (17)$$

$$p(x) = \begin{cases} x & \text{if } x > 0 \\ 0 & \text{otherwise} \end{cases}, \dots (18)$$

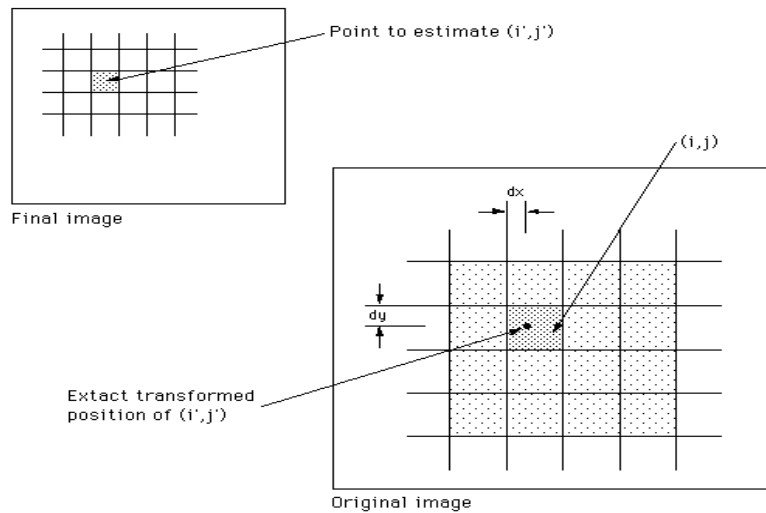


Figure 1-the Resampling Process [6].

3. Image Fusion Methods

Various statistical and spatial frequency methods were used to integrate optical images. Performs a variety of statistical variables on different image ranges based on the LMM; LMVM; RVS and LCM applied to different images. Statistical consolidation techniques used in solving the main problems in the distortion of the color image of fissile and deal with the operator (or data) group. This technique is different on other integration techniques in; the statistical variable uses, such as the least squares; the average local link or contrast with the local average correlation techniques to find the best suited between the gray values of the ranges of images that are integrated and adjust the contribution of individual bands as a result of the merger to reduce the distribution of color. As well as uses a set of fixed methods to estimate the gray value relationship between all input ranges in order to eliminate the problem of data group adoption (i.e, reduce the impact of data discrepancy) and automate the integration process.

In our work, we have been relying on the LMM and RVS methods

3.1 Merge LMM Technique

This method is based on a candidate matching density adaptive; this filter is used to modify high-resolution images to low-resolution radiation measurement channels. This filter was specifically designed in order to minimize the difference between the merged image and the low- resolution channels, also to keep most of the original spectral information of low resolution channels [12]. The similarity of images is achieved by matching the graph images. In this study, the local filtering method was returned to match the contrast and control to be able to merge two different domains; as in equ.(19) [13]:

$$F = \frac{(\text{Band}_2^{\text{high}} - \overline{\text{Band}_2}) \times \sigma_{\text{Band}_1}}{\sigma_{\text{Band}_2}} + \overline{\text{Band}_1^{\text{low}}}, \dots \dots \dots (19)$$

Where F is the fused pixel, while Band₁ is the lower spatial resolution band (image A), and Band₂(image B) is the other band. The LMVM method was applied by using a sliding window of dimensions 3×3 pixel.

3.2 Merge Using RVS Technique

This technique is based on internal relationships. Because of multiple regressions, a variable is used as a linear function for multivariate data that will have a maximum bond with uncompressed data. In the fusion of the image, the regression procedure is used to determine a linear combination (alternative vector) channel image can be replaced with another image channel [14]. Integration can be expressed by the simple regression shown in the following equation (20)[5, 15]

$$F_k = a_k + b_k \cdot B, \dots \dots \dots (20)$$

The measurement standard *a_k* can be calculated by a small squares method between the reconstructed A and B images.

While the bias standard b_k can be calculated by using equation (21, 22) between the reconstructed bands multispectral A_k and B band B .

$$b_k = \frac{S_{A,Bk}}{S_{BB}} \dots \dots \dots (21)$$

Where $S_{B_2A_{1k}}$ and $S_{B_2B_2}$ are the (covariance) between B_2 with A_{1k} of band K and the (variance) B_2 respectively [15,4].

$$a_k = \bar{A}_k - b_k \cdot \bar{B} \dots \dots \dots (22)$$

Where \bar{A}_k and \bar{B} are an average of A_k and B . Instead of computing global regression parameters a_k and b_k . Instead of calculating the global regression parameters a_k and b_k in this study, the parameter is specified in the sliding window 3x3 pixel window has been applied.

4. Spatial Frequency Method

This technique uses high pass filters to model the frequency components between images A and B by injecting the spatial details into B and inserting them into image A . Therefore, the spectral information of the original B channels is not only affected by the minimum. These algorithms use classic filtering in the spatial domain technique. Such algorithms make use of classical filter technique in the spatial domain. One of the common ways to sharpen the B roads is based on HPFA [7]. This method uses standard square-shaped HP filters and high-frequency components extracted from the HPF composite filter on image A [8] by simple addition and the result is divided by two to compensate for the increase in brightness values [7]. This technique can improve the spatial resolution of any color or individual band vehicles as in equation (23) [7]:

$$F_K = \frac{(A_K + \text{Mask}_{\text{HPF}})}{2} \dots \dots \dots (23)$$

The provision of high-frequency equally is without regard to the relationship between the two images A and B . So the HPF alone will increase the edges in the result but lose a large part of the information by filtering low-spatial frequency components [7].

A flowchart for processing a sample of input images and their fused results based on statistical techniques using the three techniques LMM, RVS and HPFA are shown in Figure-2. It presents a flowchart used to obtain the merged images (C) applying the four different techniques.

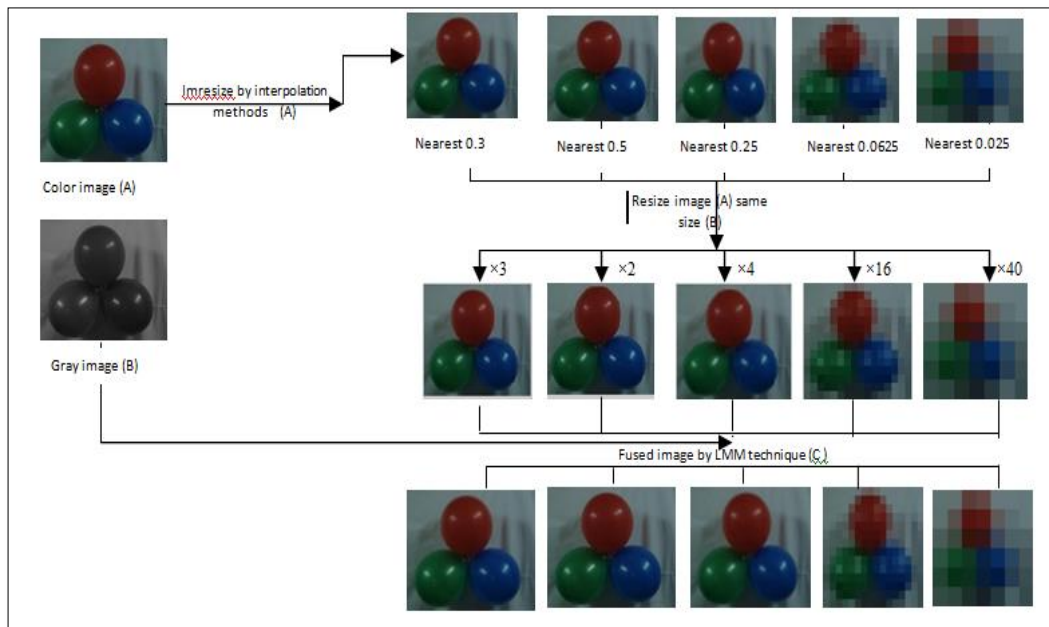


Figure 2-The flowchart of the proposed method for obtaining the fused image.

5 Merge Image Quality Measures

There are many statistical criteria used to evaluate and examine image quality before and after the integration process, including traditional quality mean μ , standard deviation STD , Absolute -Mean

Square Error AMSE, Mutual Information MI, Spatial Frequency SF, and Correlation Coefficient CC [15].

6. Practical Parts and Algorithms: Merge and Quality Measures

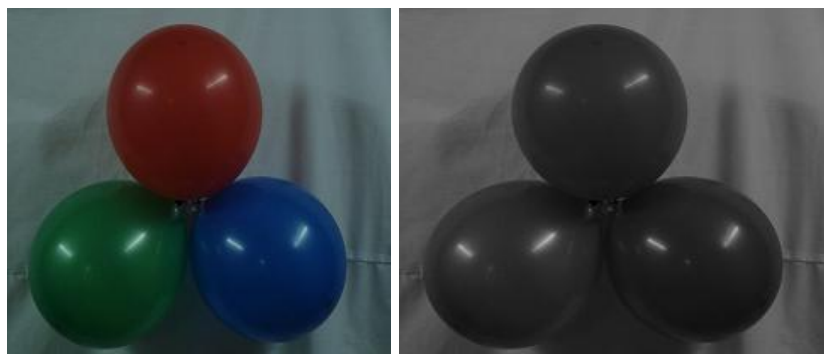
Merging techniques based on statistical techniques have been adopted (LMM, LMVM and RVS) by apply interpolation methods (nearest, bilinear and bicubic) different sizes(0.3, 0.5,0.25, 0.0625 and 0.025) on color image then Resize image with same gray image, also statistical measures have been developed to check the image quality before and after the fusion process. This method has been used to determine the optimal image and identify the best.

6.1 Tools and Software's

• Adopted optical Images

Use a pair of Optical images, one color image, an image balloons size (128×108) pixels and bit depth (24bits) and each bundle have values between (0-255). This is shown as Figure- 3a and the other image is gray scale image balloons size (256×215) pixels and bit depth (8bits) and the gray levels of intensity ranging between (0-255) and this is explained in Figure-3b.

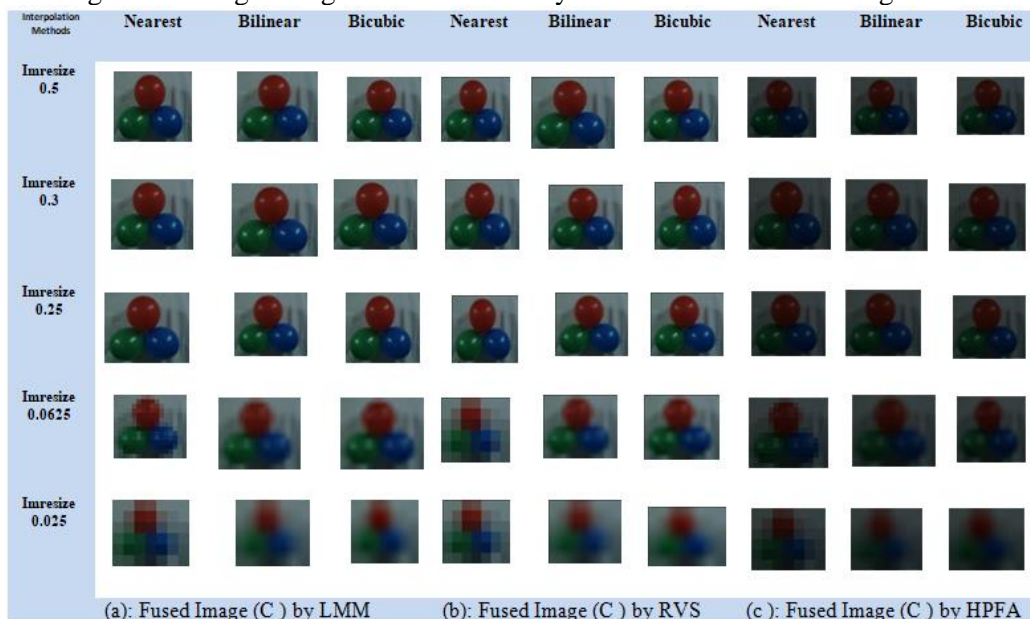
- MATLAB software is used to calculate the fusion method and statistical measures adopted.



(a) (b)
Figure 3(a, b)-Adopted images.

7. The Introduced Quality Measures Techniques

The Resize color image (A)and gray image (B) in Figure -3 were merged based on statistical and spatial frequency methods to produce the fused image (C) using LMM , RVS and HPFA respectively, as shown in Figure -4 Using the algorithm described by the flowchart shown in Figure -5



(a): Fused Image (C) by LMM (b): Fused Image (C) by RVS (c): Fused Image (C) by HPFA
Figure 4 (a, b, c)-Represents the fused image (C) using adopted methods.

Flowcharts for image edge analysis process and used in this work are presented in Figure -5

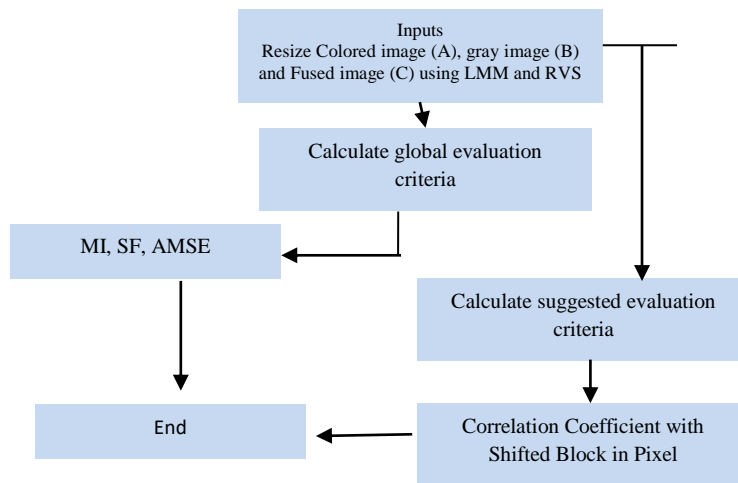


Figure 5-The flowchart for the algorithm using in the edge analysis process

8. Quality Evaluation Results

The quality evolution of the resulted merge images is performed by using several quality measures. These standards can be categorize into two types: the first type is the first type, which depends on the image region (mean μ , standard deviation STD, Mutual Information MI, and Spatial Frequency SF and Absolute Mean Square Error $AMSE_{t,e,h}$), while the second type is based on evaluation the quality in homogenous image regions (Correlation Coefficient calculate during shifted block ten pixels)[4,5]

8.1 Results and Discussion

Some statistical criteria's were calculated to check the quality of the images resulting (C), and after studying the merge methods (LMM, RVS and HPFA) for the three interpolation methods(Nearest, Bilinear and Bicubic) and obtain the results proved that the interpolation method(bicubic) give the best result to merge this method, according to the results of the quality criteria that have been relied up in the study and the results as shown in Figure-(6a), Figure-6b and Figure-(6c) respectively.

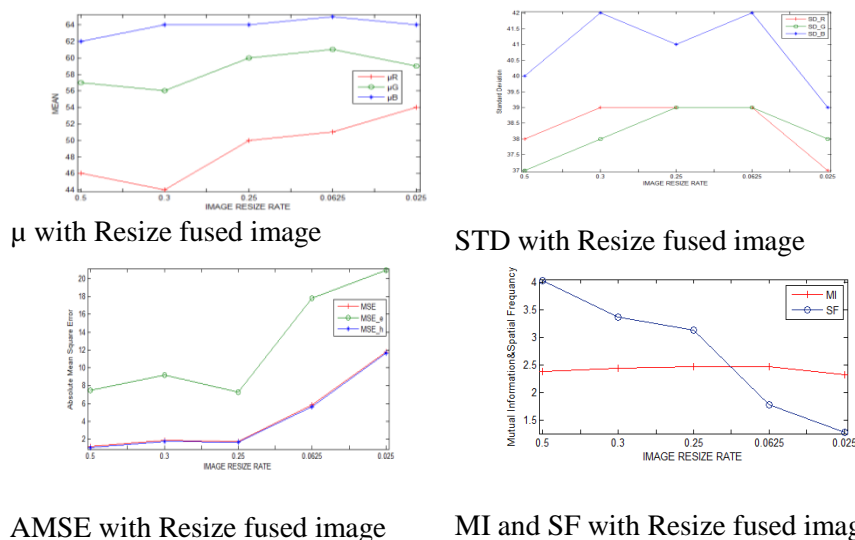


Figure 6 (a)relation between some criteria's (μ , STD, AMSE and MI, SF) with Resize bicubic interpolation fused image by LMM.

Form Figure -6a noticed that mean is approximately constant for all color bands (RGB) except for a clear decrease in the size (0.3-0.0625) then high values, indicates the high intensity at that size. While standard deviation decrease in R and G bands then romaine constant at the size (0.25-0.0625) then low

where change signification in R band for all sizes, but Absolute Mean Square Error were gradually increased for the (total AMSE_t, homogeneous AMSE_h and edge regions AMSE_e), as for the Mutual Information values were constant for all sizes either Spatial Frequency decrease value gradually for all sizes.

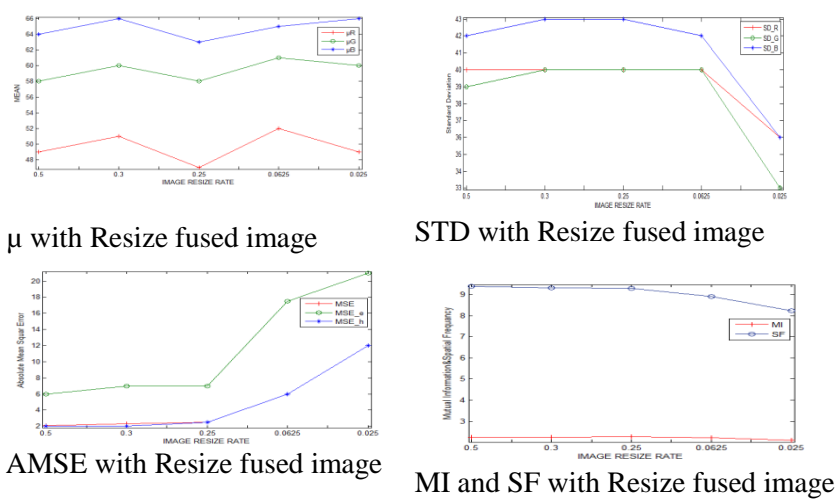


Figure 6 (b) relation between some criteria's (μ , STD, AMSE and MI, SF) with Resize bicubic interpolation fused image by RVS.

● Figure-6(b) showed mean is approximately change signification for all color bands (RGB) at all size. While standard deviation remains constant and high values for all size except size (0.0625, 0.025) low value. As for the Absolute Mean Square Error values were gradually increase for the (total AMSE_t, homogeneous AMSE_h and edge regions AMSE_e), but Mutual Information values were constant for all sizes either Spatial Frequency it's note values were constant for all size except (0.0625, 0.025) low values.

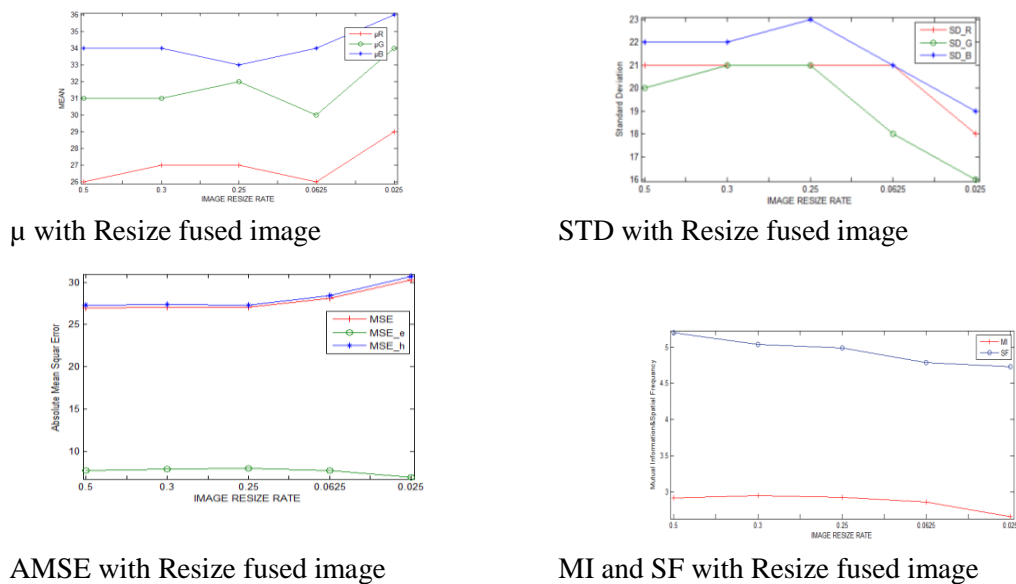


Figure 6(c)-relation between some criteria's (μ , STD, AMSE and MI, SF) with Resize bicubic interpolation fused image by HPFA

• Figure -6© explained that means approximately change signification value for all color bands(RGB) at the all size except(0.025) increase values. While standard deviation change signification for all color bands (RGB) at all size except size (0.025) decrease value. As for the Absolute Mean Square Error remain constant value for all size for the total and homogeneous $AMSE_h$ while the high in at the size (0.025) as for the edge $AMSE_e$ remains constant for all size. Mutual Information values were constant for all sizes except (0.025) low, Spatial Frequencies values were constant for all size except (0.0625, .025) value.

In this study we have been suggested correlation criterion to estimate homogeneity in different image regions and applied this on images in Figure-3 before and after adopted integration process (LMM, RVS and HPFA) during taking five blocks of different regions in the image and different sizes (20×20) and (10×10) work shifted to block per ten times where observed from the results that whenever shifted blocks per pixel note decrease correlation and before fusion process as shown in Figure -7

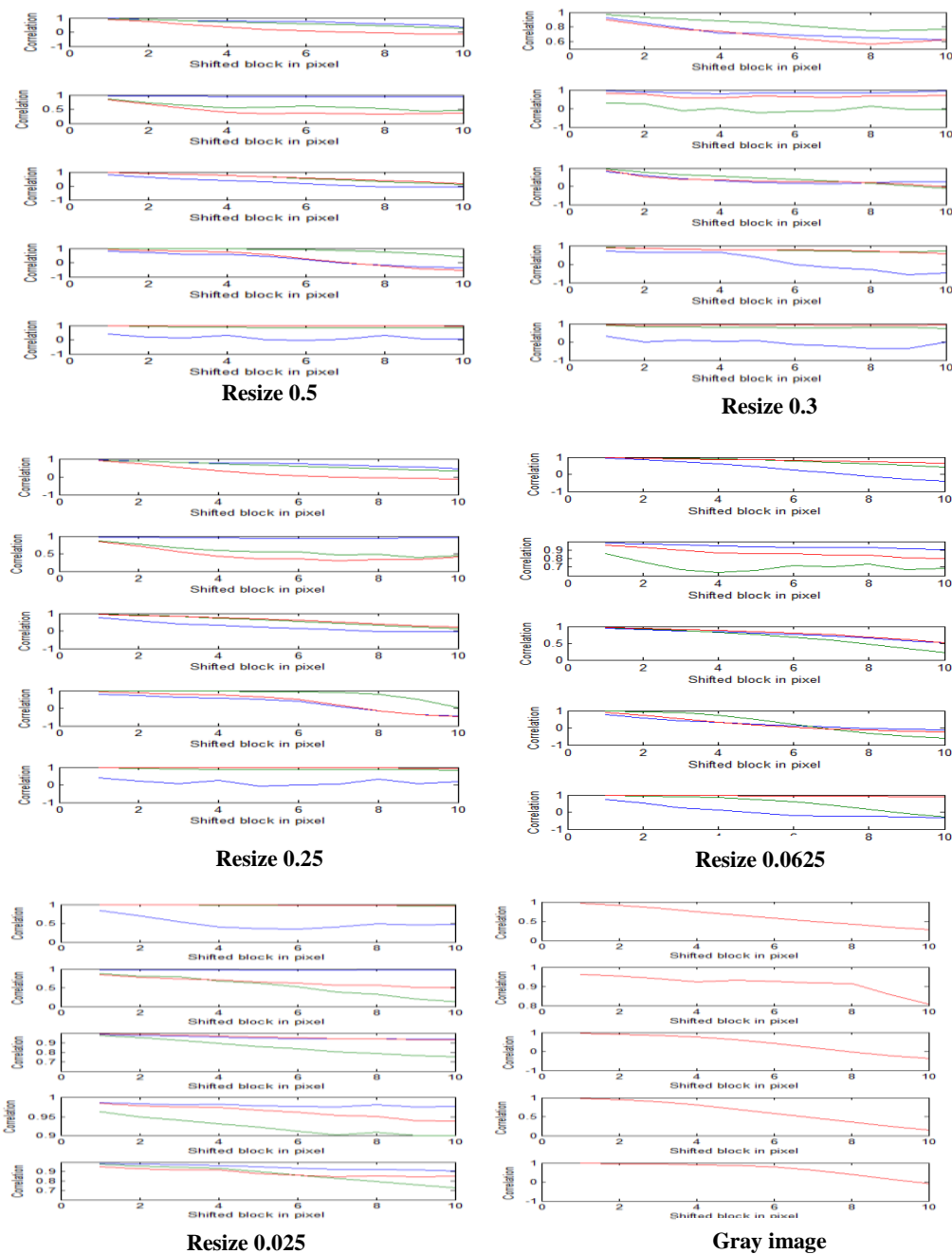


Figure 7-relation between Correlations with Shifted Block in Pixel by Bilcubic Interpolation Method before fusion process

Correlation coefficient has been evaluated quality with shifted blocks in pixels by using three interpolation methods; found that the best one was bicubic interpolation.

- The criteria of this evaluation were best seen in image sizes (0.0625, 0.025, 0.25, 0.5 and 0.3) respectively. LMM technique gave a strong degree of correlation and good because these images have been adding a new function has made values less than the values in the original image as shown in Figure-8a.

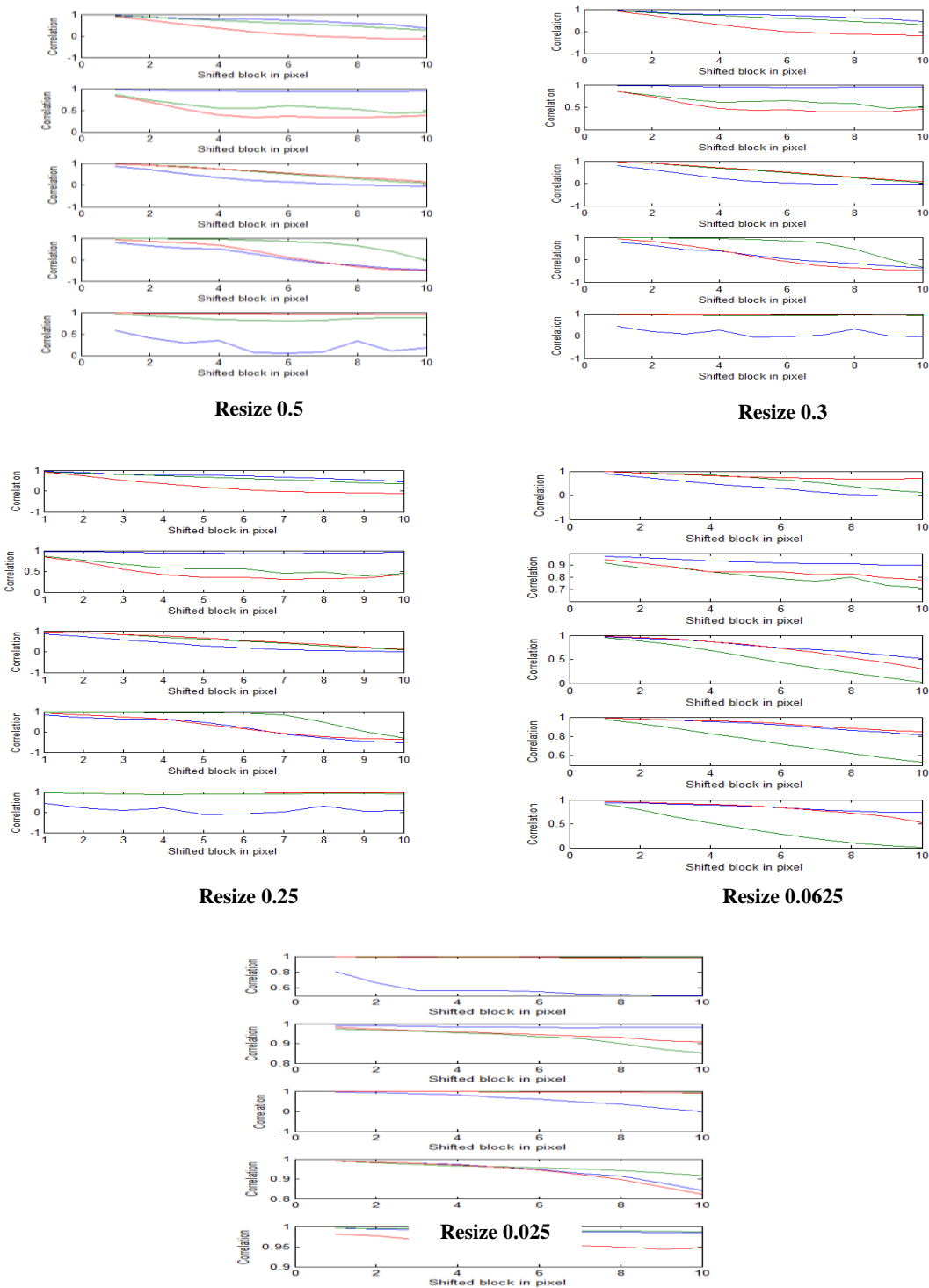


Figure 8a-relation between Correlation with Shifted Block in Pixel by Bilcubic Interpolation Method by LMM fusion technique

- The criteria of this evaluation were best seen in image sizes (0.025, 0.0625, 0.25, 0.3 and 0.5) respectively. RVS technique gave a strong degree of correlation too as shown in Figure-8b.

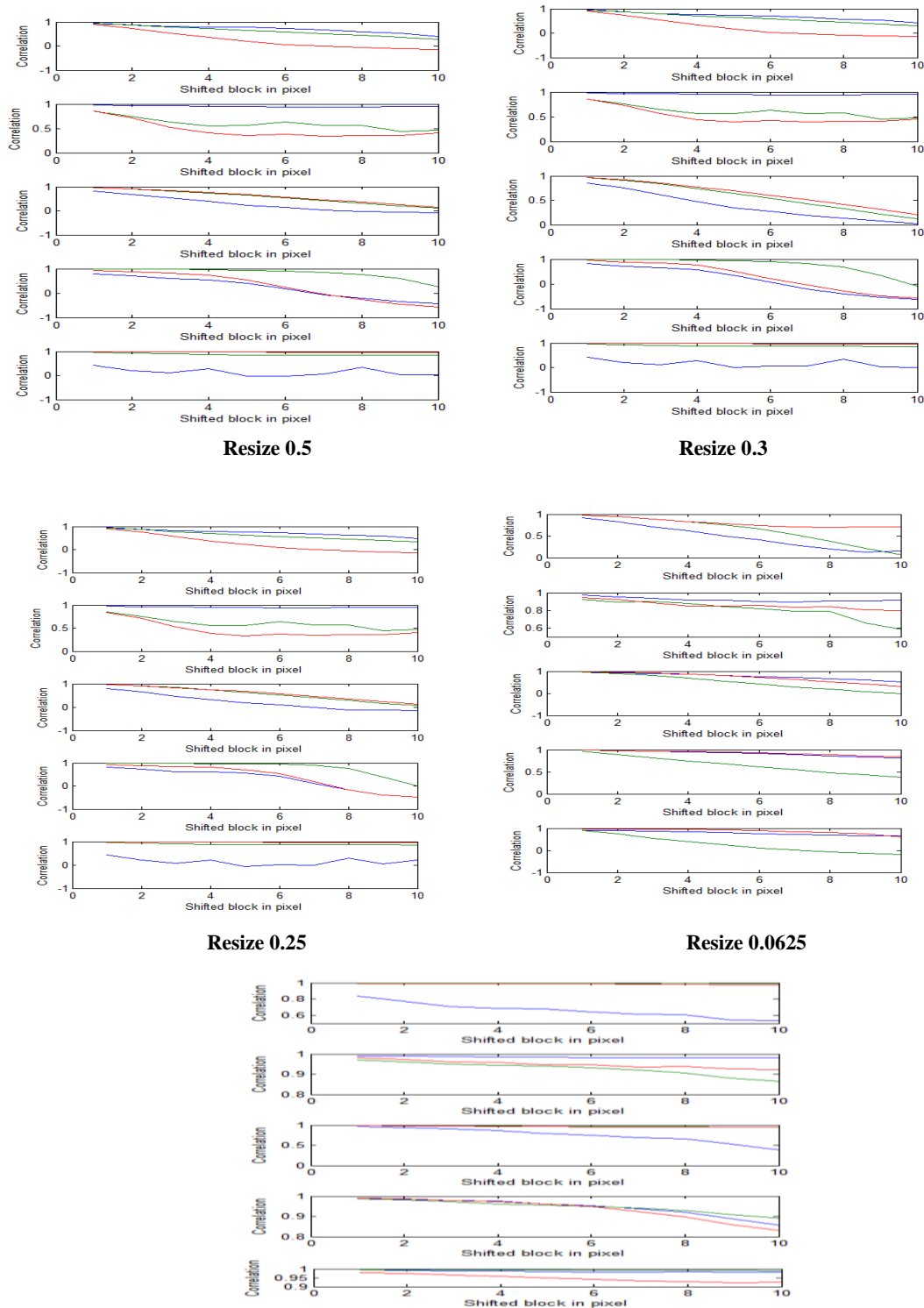


Figure 8b-the relation between Correlations with Shifted Block in Pixel by Bilcubic Interpolation Method by RVS fusion technique

- The criteria of this evaluation was best seen in image sizes (0.025, 0.25, 0.0625, 0.5and 0.3) respectively. HPFA technique gave a strong degree of correlation too as shown in Figure-8c).

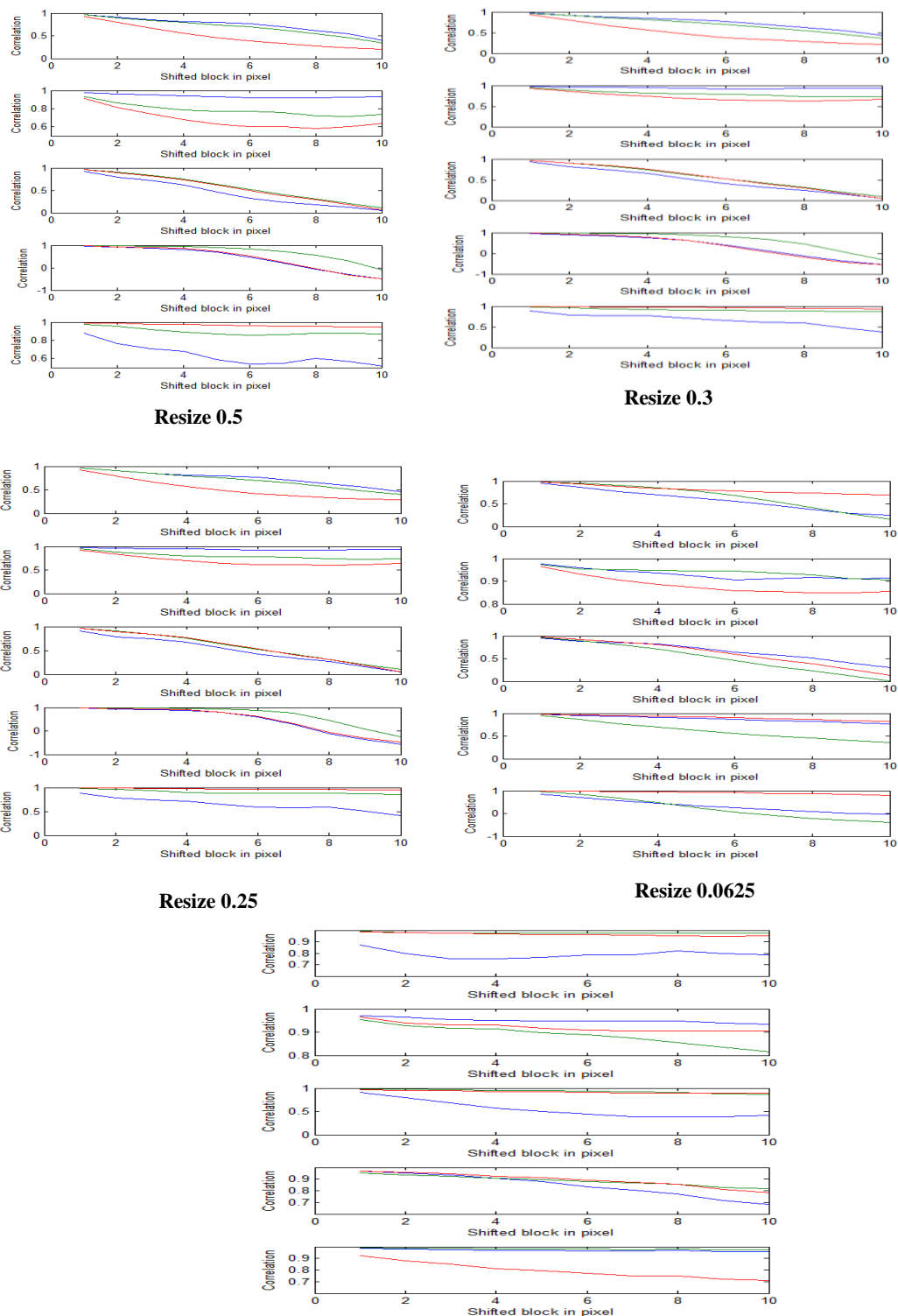


Figure 8c-relation between Correlations with Shifted Block in Pixel by Bilinear Interpolation Method by HPFA fusion technique

9. Conclusions

This study shows an optical image fusion based linear interpolation methods. Effective traditional statistical criteria used to check quality image before and after fusion where the best results criteria for optical images in RVS fused technique almost results convergent and fixed as the smaller size of the image, also Increase the value of Absolute Mean Square Error refers to the amount of information with the error. As for the Mutual Information and Spatial Frequency are oscillatory values and changing. The second, correlation method is to evaluate the homogenous region. Both methods show

good and efficiency results of the fused image, and bicubic interpolation method gave the best results of the optical image.

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